Popular Astronomy

Vol. XLVI, No. 5 MAY, 1938 Whole No. 455

The Double Variability of 12 Lacertae

By E. A. FATH

The short-period variability of 12 Lacertae was discovered independently by Stebbins[1] and by Guthnick[2] in 1917 and 1918, respectively. Each of these observers reported variations in the amplitude of the light curve.

The radial velocity of the star was studied by Adams,[3] Young,[4] and Christie.[5] The observations of Young established a spectroscopic period of $0^d.1930890$. From the spectroscopic observations it was evident that the value of the amplitude of the velocity curve (2K) had a range of about 50 km/sec. This fact, combined with the variation in the amplitude of the light curve, led the writer to a further study of the star with the photoelectric photometer of the Goodsell Observatory in the summer of 1937, to see if these variations in amplitude were periodic in the same manner as those he had found for δ Scuti.[6] This note will be devoted to a preliminary report on the photometric observations of 1937.

The star 8 Lacertae was used as a comparison star. Guthnick suspects 8 Lacertae to be slightly variable. This point will require further investigation.

Observations extending through several hours were obtained on each of 14 nights between August 4 and October 14, 1937, on the following dates:

J. D. 2428750	J. D. 2428766
752	768
754	769
757	795
759	798
760	799
761	821

The observations on J.D. 2428795 were made by Dr. R. S. Zug; those on the other dates by the writer.

The light curves obtained on the first 10 dates are shown in Figure 1. The decimal of a Julian Day is indicated at the top of the figure. The order is from the top down in the left and then in the right half.

The spectroscopic period obtained by Young, $0^d.193089$, fits the light curves fairly well. Assuming this to be the correct period of light variation the observations give the following heliocentric formulae:

$$\text{Max.} = \text{J.D. } 2428750.705 + 0.193089\ E$$
$$\text{Min.} = \text{J.D. } 2428750.796 + 0.193089\ E.$$

The light curves show the same general characteristic as those of δ Scuti, namely, no two curves are alike.

After some preliminary tests it became evident that there was a period of very nearly $7^d.5$ in the amplitude of the light curves which, after comparison with the amplitude of the curves of Stebbins and Guthnick, became $7^d.496205$. The formula

$$\text{Min. amplitude} = \text{J.D. } 2428747.75 + 7.496205\ N,$$

where N is an integer, was used for the calculation of the phases of the

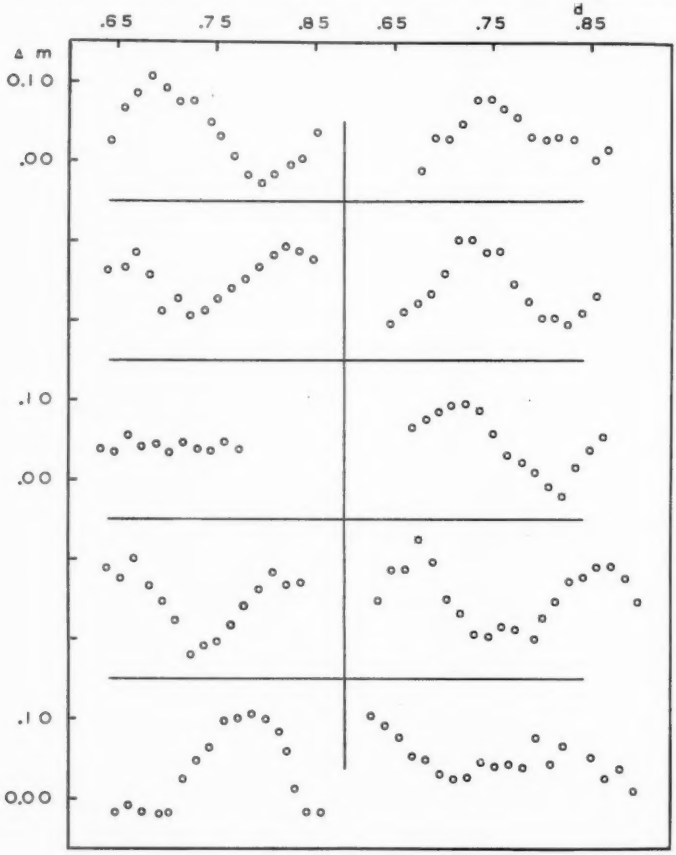


FIGURE 1

LIGHT CURVES OF 12 LACERTAE IN AUGUST, 1937.

times when the amplitude of the light curves could be measured. This was the case for two of Stebbins' curves in 1917 (large open circles in Figure 2, top), five of Guthnick's curves in 1919 and 1920 (small filled circles) and the 14 curves from this observatory in 1937 (small open

circles). Every effort to fill the gaps at about phases $0^d.5$ and $2^d.0$ was frustrated by clouds.

The same formula was then applied to the 11 radial velocity curves obtained by Young and Christie between 1918 and 1924. The results are plotted in the lower half of Figure 2.

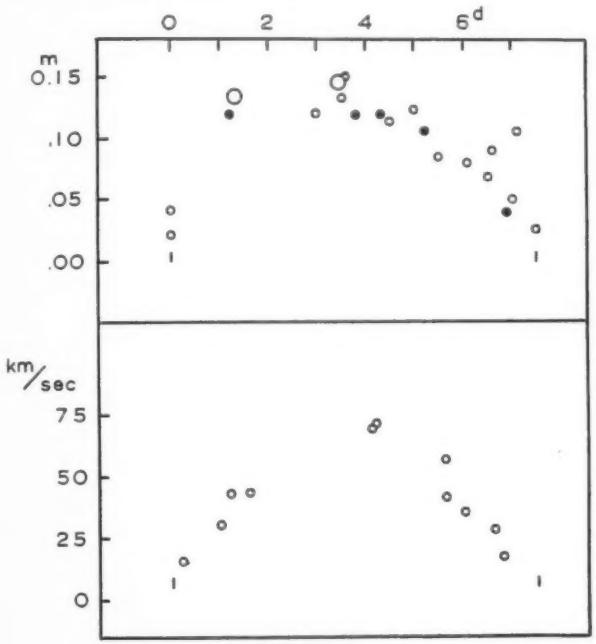


FIGURE 2

Upper half. Amplitude of light curves of 12 Lacertae plotted with a period of $7^d.496205$. Large open circles represent Stebbins' observations in 1917; small filled circles, those of Guthnick in 1919 and 1920; small open circles, those of Goodsell observers in 1937.

Lower half. Amplitudes of the velocity curves of Young and Christie, 1918-1924, plotted with the same period and initial epoch.

Figure 2 thus shows that for all published photoelectric observations between 1917 and 1937 which allow the amplitudes of the light curves to be obtained the amplitudes fall approximately on a curve which has a period of $7^d.5$ and a range of about $0^M.1$. It also shows that the amplitudes of the velocity curves from 1918 to 1924 fall on a similar curve with a range of about 50 km/sec. While there is no evidence that the amplitudes of light and velocity curves are directly related, as in the case of δ Scuti, since simultaneous observations were not made, yet it

seems reasonable, in view of the data shown in Figure 2, to assume that such is the case.

The simplest explanation of the periodic character of the amplitudes of the light curves is that of an interference between two periods of variation, the one the primary period of $0^d.193089$ and the other of about the same value, which are in phase every 7.5 days.

The simplest explanation of the variation itself is that of pulsation. This is indicated by the velocity curves. Whether or not the difficulties which Sterne[7] finds in δ Scuti are also present in the case of 12 Lacertae cannot be decided at present because of the small number of light and velocity curves available.

It is planned to continue the study of 12 Lacertae during the coming season.

GOODSELL OBSERVATORY, CARLETON COLLEGE,
NORTHFIELD, MINNESOTA, APRIL 18, 1938.

[1] POP. ASTR., **25**, 657, 1917.
[2] *Astr. Nach.*, **208**, 219, 1919.
[3] *Ap. J.*, **35**, 179, 1912.
[4] *Pub. Dom. Obs.*, **3**, pt. 3, 1915; *Pub. Dom. Astroph. Obs.*, **1**, pt. 2, 1918.
[5] *Pub. Dom. Astroph. Obs.*, **3**, 209, 1925.
[6] *Lick Obs. Bull.*, **17**, 175, 1935; **18**, 77, 1937.
[7] *Ap. J.*, **87**, 133, 1938.

The Sun

By JOSEPH M. SYNNERDAHL

Because of the vastness of my subject, I shall be compelled to confine myself to one or two phases of it.

First of all, let me say a few words as to the importance of the sun to us here on the earth. All terrestrial life and activity are conditioned on the maintenance of the heat and light of the sun. A star, or even a considerable number of them, might be blotted out, and not one in ten thousand would notice their absence. No appreciable effect on terrestrial affairs would be produced. The planets might all disappear, and their absence would scarcely affect us at all. The moon might be destroyed, and yet affairs on the earth would speedily adjust themselves to the new conditions. The mariner on a long voyage would be put to some inconvenience in finding his longitude; and we should greatly miss her kindly light. The tides would become less, and would change in character; and in a good many other ways the loss would be felt. But we could do without the moon or the planets or the stars and not suffer greatly on account of their absence; they are not necessary to our existence.

But suppose that the sun were to cease giving us heat. In a month all life would have ceased, and in a very short time after that, practically all inanimate motion. Clouds and winds and rains would be no more. The streams would all freeze solid or run dry and everything would be as

dead as is now the case on the moon.

The sun is directly and indirectly the source of nearly all the available energy on the earth. Practically all the forces which man has tamed and harnessed to do his work derive their power from the sun. The wind which turns the mill or wafts the ship across the ocean owes its existence to the heat of the sun. The unequal heating of the air in different latitudes over the land and ocean causes changes in the density of atmosphere and the various currents are an effort to restore equilibrium.

The force which turns the water-wheel is gravitation. It is the force which causes all the matter of the earth to exert a pressure toward the center of attraction, and which causes the flow of water in all streams and rivers. But left to itself, the water would all collect in the oceans and would no longer be a source of power to us, being at its lowest level. The source of the energy is after all solar. The heat of the sun vaporizes the water and distributes it over the earth in the form of rain, and as a portion of it falls on land of a higher level than the ocean, we can avail ourselves of that portion of its energy and make it do work for us as it runs down toward the sea.

Again, all the gas and oil, the wood and coal, which we burn to give us light and heat and mechanical energy, pass on to us only what they borrowed long ago from the sun. The plant in its growth stores up the heat of the sun, not directly as heat but as chemical affinity. It grows by taking up the carbon dioxide of the air, and decomposing it through the agency of sunlight and heat. New compounds are formed of carbon, hydrogen, and oxygen, which store up the solar energy in the form of chemical affinity, and stand ready to give it back to us in the form of heat and light. All our coal-beds are nothing else than vast storehouses absorbed and transformed ages ago, and ready for man's use. Our steam engines are driven by the sun whether we concentrate directly its rays on the boiler by burning glass or mirror, or whether we burn coal which has lain underground out of sight and reach of the sun for millions of years. The sun lights our homes at night by electricity, gas, or oil, as truly as it does by day.

Again, all the physical activity exhibited by man and the animals is but a manifestation of energy derived from the sun. The muscular energy of a man, the work he does, comes from the chemical combination of the food he eats and the air he breathes and can be no greater in amount than that in the food and air before they are assimilated; and the food derives its energy from the sun. Considered in this sense as a machine he is one of the most economical ever constructed. When we build an engine which will do a man's work on a consumption of three or four pounds of beef and bread a day or their equivalent in coal, we shall have made an immense advance in mechanics.

Now do not misunderstand me and think I maintain that the sun is the cause of all life. There is to my mind no evidence that any form of life

can be created apart from the decree of the divine Creator. The soul is distinct from the material environment in which it finds itself. But the physical part of the living organism must obey physical laws. If a man does physical work we must look to some physical cause for the force used, otherwise the great Law of the Conservation of Energy breaks down.

The sun then is a worthy object of study, and has always occupied the attention of astronomers since science began. For a long time the study of the sun was a study of its place among the stars. Attempts were made from time to time to account for the appearance of things in the starry heavens. Finally Copernicus showed that the sun was probably the center about which the earth and the other planets revolved, and shortly afterward Kepler showed that the motion was elliptical and equi-areal. Then came Newton who bound up all the scattered facts in the Law of Universal Gravitation. Since his time this part of the science, Physical Astronomy, the application of the law of gravitation, has been developed until it is well-nigh perfect. But this, the older astronomy, deals with the sun and the planets as wholes, and regards them only on the side of their mass or attracting force. Another branch of astronomy has been developed, almost wholly within the last century, which deals with the planets as individuals, which studies their physical condition and characteristics, their atmospheres, their surfaces of land and water, their light and heat, etc. This new department of the subject has been called Astrophysics and is not to be confounded with Physical Astronomy which deals with the law of gravitation only.

It is to this aspect of the case as developed by the New Astronomy that I must confine myself, and, before going further, it may be well to say something about the instruments used in the investigation of solar phenomena. These are the telescope, the spectroscope, and the spectroheliograph. The telescope is an instrument with which in the form of an opera glass you are doubtless more or less familiar. The astronomical telescope differs slightly in the form of eyepiece, but the method of producing the desired effect, that of bringing the object looked at nearer and making it more distinct, is practically the same in both. If our eyes were sufficiently sensitive, this one great use of the telescope would vanish.

But the spectroscope is an instrument of different character. The telescope merely improves our eyesight, while the spectroscope does something which no eye, however perfect, ever could do. By it we may determine the chemical constitution of certain portions of the sun and, perhaps, learn some things about its physical condition. A special kind of spectroscope, the spectroheliograph, takes pictures of the sun in the light of a simple chemical element. The principles on which the spectroscope rests are as follows:

Ordinarily white light is a mixture of light of all the various colors from red to violet. If now a beam of this light passes obliquely from

one medium to another as from air to glass or water, it is bent out of its course; and, what is more, the red rays are bent out of the course less than the violet. In passing out of the glass or water into the air again there is another bending back to their original directions, if the two surfaces of the refracting medium are parallel, as in a piece of ordinary window glass, or there is greater separation if the glass is wedge-shaped. If the beam is a very narrow one, in place of the beam of white light emerging from the prism we shall have a ribbon of light showing all the colors of the spectrum. We get this so-called continuous spectrum whenever we analyze light from an incandescent solid or a gas under pressure.

When, however, the source of light is glowing gas we find a spectrum of a different kind. If for instance the source of light be glowing sodium gas, we get, instead of the ribbon of colors as in the former case, two very bright lines of light in the yellow; part of the spectrum, the other parts being entirely wanting. Other gases give other bright lines, each one in its own characteristic series, always under the same conditions in the same places. Now suppose a beam of white light passes through a layer of these gases, we shall find that the continuous spectrum will be broken up; that numerous dark lines are to be seen in it, and that these lines occupy the places that would be occupied by the bright lines of the various gases, if they, instead of the other body, were giving off the principal light. The spectrum of the sun is of this character, a spectrum primarily containing all the colors, but interrupted in many places by dark lines. We infer the existence of terrestrial elements on the sun by the coincidence of the dark lines in its spectrum with the bright lines of the substance, which we may produce in our laboratories by bringing it to a state of gaseous incandescence.

It was an article of faith until after the invention of the telescope that the sun was "pure fire," immaculate, without spot or blemish, and that every other opinion was heretical. True, here and there, some individual claimed to have seen spots on it, but such claims were set down as imposture, or where explanation was impossible it was thought that these apparent imperfections were due to bodies between us and the sun thereby shutting out part of its light. It was not until toward the close of the last century that telescopes of any great power, and adapted for solar work were constructed; thus the beginnings of our real knowledge of the structure and physical condition of the sun are scarcely a century old. Within the last third of a century more has been learned in these matters than was discovered in previous ages.

When we look at the sun with a good telescope provided with a suitable eyepiece, we see that its surface, instead of being a uniform expanse of light-giving substance, presents a curiously mottled appearance, being covered over with small granules brighter than their surroundings. They have been called "willow-leaves," "rice-grains," etc. They are usually rounded or oblong, generally dispersed, apparently at random over the surface, but occasionally with some appearance of grouping in

whirls or curves. Perhaps the nearest approach to a terrestrial illustration is a mass of curds in whey. This layer of light-giving material is called the photosphere. The granules are not permanent but change from day to day, or even in much shorter intervals.

But not infrequently there are to be seen, in addition to these granules, spots on the surface of the sun, sometimes of an enormous size, occupying a considerable fraction of the sun's surface. Sometimes they are large enough to be seen by the naked eye, and we have records of their appearance long before the invention of the telescope. But they did not attract much attention until it was definitely settled that they were truly solar and not projections of intervening objects on the sun's surface. For about one hundred years their study has been diligently pursued, but many problems connected with them are still unsolved. When a complete account has been given of them, with all their causes and laws, and effects, we shall have gone far toward giving a solution of most of the problems in regard to the solar structure, for almost all solar phenomena seem to be in some way connected, as cause concomitant or effect.

The normal sunspot consists of a dark central portion called the umbra, and a penumbra consisting of filaments of the photosphere reaching in around the edges of the umbra like a set of gigantic fingers. Generally the umbra is the first portion formed. The life of a sunspot varies from a few days to as much as eighteen months.

Perhaps the first bit of knowledge gained from the study of the spots was the fact of the rotation of the sun on an axis in about twenty-five days in the same direction as the earth. A spot takes a little less than two weeks to cross the sun's disc. If its life is long enough it may be observed for several rotations. It was advanced a little more than one hundred years ago that the spots are depressions. This seemed to explain the change in relative positions of umbra and penumbra as the spot moves across the sun, as well as the fact that in the course of some of the larger spots a distinct notching of the limb of the sun may be seen as the spot comes to the right position. However, Professor Young expressed considerable doubt in his own cautious way that sunspots were always depressions in the photosphere, and later Dr. Abbott reached the definite conclusion that the level of sunspot phenomena as seen by the ordinary observer differs very little if at all from the surrounding bright surface of the sun.

The normal shape of the spot is oval, with the nucleus or umbra in the center and the filaments or penumbra reaching in radially or nearly so. But in many instances perhaps in the majority, and especially as the spots tend to break up, these conditions are not all fulfilled. The umbra is not central, and the filaments of the penumbra do not reach straight in toward the center, but are curved and twisted into all sorts of shapes. Frequently there is strong evidence of whirling or vortical motion; that is, within the spots, the filaments arranging themselves like blades of eelgrass in an eddy.

The umbra of the spot is dark only by contrast. It is really brighter than limelight; besides when viewed by a high-power telescope at a time when the atmosphere is quiet, it is generally overlaid by a delicate tracery of photospheric matter in plume-like forms. If gases at high levels whirl with sufficient velocity, they develop a funnel-like extension, and in the center of the storm the expansion of the gases due to their rapid rotation cools them and thus produces a comparatively dark cloud which we see in a sunspot. It was believed that disturbances giving rise to sunspots were confined to the upper regions of the solar atmosphere; even Professor G. E. Hale expressed this view but modified it later. After a rather elaborate investigation by Dr. St. John about twenty years ago, Professor Hale's original sunspot hypothesis becomes only partially true. According to new theory, a column of gas moves upward from the interior of the sun towards the surface of the photosphere, setting up a vortical motion upward and then outward owing to differences of velocity of adjoining surfaces or irregularity of structure in the circumambient gases. As a result of expansion in the central portion of the vortex, cooling sets in, and a comparatively dark cloud—the sunspot umbra—is formed. And, since electrically-charged bodies exist in the solar atmosphere, "a rapid flow of negative ions sets in toward the cooler gases at the center from the hotter gases without. These ions, whirled in the vortex, produce a magnetic field."

As the spot grows older and gets ready to disappear, it does so by the gradual encroaching of the penumbra and the surrounding photosphere on the umbra.

These spots do not appear everywhere on the surface of the sun, but are confined mostly to two zones north and south of the equator. Records of spots farther than 45° from the equator are rare and perhaps not very well authenticated.

Another curious phenomenon connected with the spots is their periodicity. While we can not predict that a spot will appear at any particular time and place any more than we can predict the weather a year in advance, yet we can, with fair accuracy, predict for a number of years ahead whether there will be many or few spots each year. The number and character of sunspots which have appeared have been diligently recorded since 1826, and it is found from a study of these records that once in eleven years we have a maximum spottedness, that in the years preceding there is a gradual increase and in the years following a more gradual diminution to a minimum between the two maxima. At the date of this publication we are near a sunspot maximum. The cause of this phenomenon is still unanswered, and engages much attention.

Another noteworthy phenomenon presented by the spots is their motion. Like storms on the earth they have a motion of their own on the sun in addition to their apparent motion due to the solar rotation and what is the most curious, the spots nearest the equator move faster than those farther north and south. The rotation of the sun, judged from

the spots on the equator, is 25 days, while in latitude 40° the spots give a time two days greater. Hence we deduce that the sun has an equatorial acceleration, as expressed by Spoer's empirical formula:

$$X = 8°.55 + 5°.80 \cos L$$

Where X = Daily Motion of a Sunspot; L = Latitude of Sunspot. This equation breaks down for high latitudes but applies well within the range of latitude that the sunspots occur.

Until a little more than twenty years ago, any knowledge of what goes on outside the photosphere of the sun was to be gained only during a total eclipse and some of the phenomena still refuse to exhibit themselves to us except at such a time, the amazing revelations of the spectroheliograph notwithstanding. The opportunity for such study is very limited. Considering the whole earth, a total eclipse of the sun is not a very rare phenomenon, they occur every year or two but that portion of the earth over which the eclipse is total is so small, and the accessible land surface on which alone the most valuable observations can be taken is so restricted, that a good many of them are not available for astronomical purposes.

In addition, the duration of totality is only about three minutes on the average and never as great as eight minutes. I have never heard of any one who has seen more than ten eclipses and I suppose no one has had a half hour for their study. It is small wonder, therefore, that our knowledge of these phenomena is still imperfect.

Considered merely as a spectacle a total solar eclipse is one of the grandest which the whole science of astronomy affords, and once seen is never forgotten. For any given locality such an eclipse occurs not more often on the average than once in three hundred sixty years. So that comparatively few people have actually seen one. The sight well repays a long journey. Whenever one occurs in any accessible part of the world, the line of totality is occupied by astronomers usually in parties which come thousands of miles for the sake of two or three minutes' sight. Sometimes they do not get it. A great many persons went all the way to Russia to take observations on the eclipse of 1887, and saw nothing on account of rain and clouds, except for the general darkening and lightening up again. A later expedition met the same fate. They had better luck in September, 1923, in California. The most important eclipse of recent years, which occurred in January, 1925, and whose path of totality crossed the northeastern states of the Union, from a point at sea through New York harbor to Duluth, Minnesota, a strip three thousand miles long and one hundred miles wide, approximately, was studied and photographed under very favorable atmospheric conditions in the East, but was lost to the observer in the Middle West on account of rain and clouds. These eclipses of the sun have been studied with the greatest care for about half a century for the sake of scientific knowledge, while from the earliest historic times they have excited the awe and curi-

osity of men. Only total eclipses are available for the phenomena we are studying, as they are seen only at such times or perhaps faintly just before or just after totality, but not conspicuously enough to attract attention.

Just before totality the sky assumes a peculiar livid hue. The light now comes from the regions of the sun near the edge where the light is much fainter and of a somewhat different character from that of the center of the disc. It is a very awe-inspiring sight and for one ignorant of astronomy a very terrifying one. During totality the darkness is not much if any greater than at full moonlight, and if the sky be covered with clouds, the darkness is generally not as great as if the air is clear, perhaps generally owing to the reflection from clouds outside the line of totality.

As long as any portion of the sun is uncovered, there is no special change in its appearance except in its shape, but as soon as the moon covers completely the photosphere, there is a complete and surprising change. Instead of the dead blackness which might be expected, a brilliant halo bursts out all around the edge of the moon. This halo, called the corona, which seems dazzlingly bright at its base, greenish white in color, really is scarcely as bright as the moon. It extends in all directions to about one half of the moon's diameter and often there are long streamers reaching out generally from those portions of the sun where the spots are most frequent, sometimes to an extent of millions of miles. The spectroscope shows that this corona is a composite mass. Part of its light is due to the presence of a yet unidentified glowing gas (coronium emissions), while another part seems to be merely reflected sunlight. It is evident that it is in some way a solar atmosphere, but with many points of difference from our own. A careful study shows that it is composed of streamers reaching from the sun, sometimes radial, sometimes tangential, sometimes apparently straight, sometimes curved, a continual up-rush or down-rush of matter of different densities, of different degrees of illumination. The phenomenon is very complicated from the fact that these streamers seem to emanate from all longitudes on the sun, and, as they are transparent, what we see at any one point is what may be called a composite picture of all that are in the line of sight. It has been frequently photographed and the photographs show much detail of structure, but not nearly as much as can be seen by the eye at the telescope. However, the photographs can be examined at our leisure while the corona can be seen only during the brief moments of totality or perhaps a few minutes before and after. During a sunspot minimum, it seems to be of rather a wider extent than during a maximum, which seems to connect it with the spots. It is of almost inconceivable tenuity, as comets have been known to go through it without perceptible stoppage of their motion. How the sun can sustain such an atmosphere is still one of the debated problems. It is evidently in no such state of comparatively stable equilibrium as that of the earth.

But another phenomenon presents itself down close to the edge of the sun during the eclipse. There are generally to be seen a number of rose-colored patches of light of various form, sometimes spike-shaped, sometimes like trees and foliage-covered branches, sometimes formless masses like clouds. They occasioned much speculation and it was not until the spectroscope was used on them that their true nature was determined. For some time it was not even determined whether they were solar or lunar. This point was settled by seeing that the moon passed over them, gradually covering those on the east and uncovering those on the west limb of the sun. In the spectroscope the light from these prominences consists of a series of bright lines principally those of hydrogen although other elements are present, and the inference is that they are composed of immense masses of glowing gas. Another analogous phenomenon is seen in the spectroscope for a very few seconds just at the beginning and end of totality. As long as any portion of the photosphere is in sight, the spectrum maintains its ordinary character, a continuous band broken by a multitude of fine dark lines, but as soon as the photosphere disappears, a great change takes place, and the spectrum is now made up of a number of bright lines, especially brilliant and numerous. The impression is that all the dark lines have become bright, and this is probably what takes place, but the point is still undecided. The phenomenon is so evanescent that it is impossible to count them all, but the uncertainty is mainly in regard to certain lines, and a critical examination of them would probably settle the point.

One line of reasoning is that the origin of about all the dark lines of the spectrum is in this narrow layer of heated gas not more than ten thousand miles in thickness; another that many of the lines, notably the iron lines, are formed by absorption in a higher region of the sun, and that the temperature of this reversing layer is too great for iron to exist in its ordinary state and give off its ordinary spectrum.

The upper portion of the reversing layer seems to be mainly a layer of hydrogen gas intensely heated and in a state of perpetual activity. Professor Young's comparison of this to a prairie on fire is the best that has been made, although the analogy is not perfectly complete, since the hydrogen is not actually in a state of combustion.

What prevents our being able to see the prominences at all times when the sun is visible is their faintness as compared to sunlight and the fact that they are projected against a much brighter background of dispersed light. When we screen off the direct sunlight, the dispersed light in the neighborhood of the sun is far brighter than that of the prominence but by an ingenious application of the spectroscope the prominence may be brought into view. The dispersed sunlight like direct sunlight gives a continuous spectrum. If now we by the use of a number of prisms or a powerful diffraction grating spread out this sunlight into a long ribbon of the spectral colors, each part of it will be greatly weakened and we may carry the weakening process as far as we please, as regards ordin-

ary limits. On the other hand the spectrum of the chromosphere and prominences is a bright line spectrum and the main effect of using a long train of prisms is merely to separate the bright lines farther apart without weakening them. We may thus bring the bright lines into view by weakening the background through which they are to be seen, the spectroscope scattering the dispersed light until it is weaker than the light of the chromosphere which is not so much affected by the instrument. We can thus examine the prominences whenever we please, and from a number of observations a complete record is made of all which are to be seen on a very clear day.

The prominences are continually changing, being in general not nearly as long-lived as the sunspots, and frequently change their shape and appearance in a few minutes. Unlike the spots, they are scattered over the whole limb of the sun, and are not confined to any partciular region. They are sometimes of an enormous size, approaching as their maximum the radius of the sun (as far as our observation goes this conclusion is correct). Sometimes they do not change very rapidly and retain their appearance until hidden by the rotation of the sun, while those especially in the region of frequent sunspots sometimes change their shape in a few minutes. The spectroscope often shows that they are in motion toward or from us with enormous velocities amounting at times to hundreds of miles per second. At times velocities have been observed which would be sufficient to throw the matter entirely away from the sun. Their swiftness of formation is at times almost incredible if they are jets of gaseous matter thrown out by some disturbance of internal nature as seems most likely. Perhaps in some cases it is merely transmitted impulse which sets into vibration matter already in position and merely renders it incandescent instead of transferring it from one place to another, so that what appears to us as a transfer of matter may be only a transfer of electrical excitement, perhaps, or some other form of energy.

For a good many years attempts had been made to photograph the prominences, but until the close of the last century little had been accomplished. There is a grand advantage in a photograph, namely, that it shows things as they are without any personal bias or guess work; and this personal equation enters very largely into any eye estimate of such a delicate and transitory appearance as the corona during an eclipse. The corona had been successfully photographed many times during total eclipses, but these photographs did not show as much detail as the eye observations. However, with the invention of the spectroheliograph, that special spectroscope which is able to photograph the whole sun and its surroundings with light of a single spectrum ray, the prominences may be beautifully photographed.

After disposing of the salient aspects of my subject in a rather cursory way, I shall conclude with a few meteorological considerations. Many and varied attempts have been made to connect sunspot activity with terrestrial weather. It has been advanced that at a sunspot maxi-

mum violent terrestrial storms and exhibitions of the Aurora Borealis occur with greater frequency; however such a deduction seems to lack foundation in fact and is rather the unauthenticated conclusion from accidental coincidence.

When the spots are numerous the sun sends out more radiation because of its hotter radiating surface; although the spots are cooler and so cause a contrary tendency, they occupy so little area or about 1/500 of the sun's disc that this tendency does not amount to much. Curiously, however, our land surface is cooler at a sunspot maximum probably because of increased cloudiness at that time; if it were more cloudy more solar rays would be reflected away, and there would be fewer reaching the earth's surface to warm it. However, decreased temperature at a sunspot maximum is not universal on the earth's surface. The paradox obtains that lower temperatures prevail when the sun is sending out more radiation. It may have an explanation in the change of wind directions and the unequal effects of solar heat in clear and hazy regions. After all, the weather is complicated, and predictions of it are richly fraught with fancy, so it would seem that the pretentions of meteorology can do little more than inspire a speculative turn of thought in the dignified science of Astronomy.

St. Xavier College, Chicago, Illinois.

A Model to Demonstrate the Dynamics of the Earth-Moon System

By RICHARD M. SUTTON

It was Isaac Newton who first pointed out the part played by the center of gravity of a moving system. To quote one of the corollaries of his Third Law of Motion,[1] "The common center of gravity of two or more bodies does not alter its state of rest or motion by the actions of the bodies among themselves, and therefore the common center of gravity of all bodies acting upon each other (excluding external actions and impediments) is either at rest or moves uniformly in a right line." When applied to the astronomical system of the earth and moon, this means that the common center of gravity of the two bodies must move in a straight line except for the chief "external action" due to the sun which causes that center of gravity to follow the elliptic path of the earth's orbit. While the moon is describing its orbit of 240,000 miles radius, the center of the earth is executing a monthly orbit of 3000 miles radius about the common center of gravity of the two bodies, which lies about 1000 miles below the surface of the earth on a line joining the centers of the two bodies. That "the tail wags the dog" in this manner has long been

[1] Newton's *Principia*, Law iii, Corollary iv.

known to astronomers; but to make the principle more vivid, the writer recently demonstrated[2] a simple mechanical apparatus which enables one to visualize the motion with ease. Although the principle is an old one, the demonstration affords some aspects of novelty.

The apparatus is constructed from materials largely obtainable at the 5-and-10-cent store. It consists of an inexpensive metal globe of the earth, six inches in diameter, to which a smaller globe, three inches in diameter, representing the moon is attached by a ⅜-inch rigid tube *T* 30

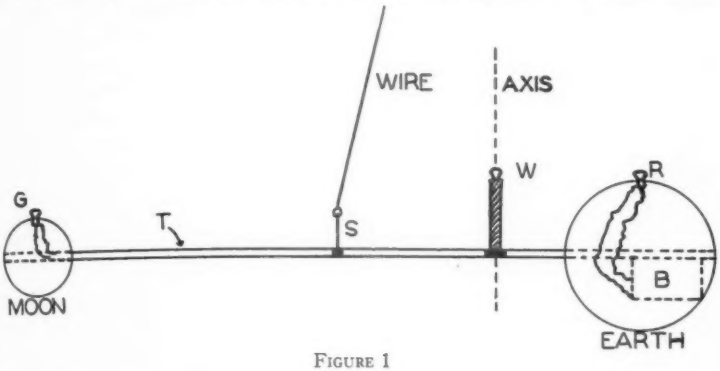


FIGURE 1

inches long, passing diametrically through both globes (Fig. 1). Inside the larger globe there is installed a receptacle to hold two flashlight dry cells *B* which furnish energy for three 2.5 volt flashlight lamps. One lamp *R* (red) is located at the north pole of the earth-globe (obviously to furnish the "northern lights"!); the second light *G* (green) is mounted in a corresponding position on the moon-globe. It is connected to the battery by wires which pass through the tubular connecting rod. The third light *W* (white) is held in a socket arranged to slide on the connecting tube so that it can be adjusted to coincide with the center of gravity of the system. The proper place to fasten this last light may be determined by balancing the apparatus on any convenient fulcrum.

The map of the earth is left intact on the larger globe; the smaller globe is painted yellow or aluminum on the side facing the earth, while the other side is painted black to represent ignorance. The three lights are connected in parallel to the dry cells and may be controlled individually by simply screwing them in or out of their sockets. The light at the center of gravity is supported three inches above the connecting tube to insure visibility throughout the motion as it is otherwise eclipsed periodically by the passage of the earth-globe. The whole system is suspended by a flexible wire three feet long attached at *S*, the midpoint of the connecting tube *T*. The upper end of the supporting wire is made

[2] Shown before the Rittenhouse Astronomical Society of Philadelphia.

secure in the chuck of a hand drill held at arm's length so that it can be turned slowly about a vertical axis. When at rest, the earth-globe hangs down because its predominant mass brings the center of gravity of the system a short distance outside the larger globe.

As the apparatus is set revolving by the hand drill the centrifugal reaction torques which are introduced by the rotation promptly bring the paths of the two globes into a (nearly) horizontal plane in an impressive manner, while the system selects a stable axis of rotation passing through the center of gravity despite the fact that the supporting torque wire is attached to the system several inches away from it. With the miniature lamps alight the apparatus presents a beautiful spectacle: the green light on the moon describes a large circle nearly three feet in diameter while the red light on the earth follows a circle one foot in diameter; but the white light at the center of gravity *remains at rest.* The effect is enhanced if the apparatus is viewed in a partially darkened room.

Inasmuch as the apparatus is designed primarily to demonstrate a basic principle of astronomical dynamics, it is scarcely necessary to apologize for the obvious departures from correct astronomical scale. In fact, if the orbit of the moon were in scale with the six-inch earth, it would be not three but *thirty* feet in diameter! Furthermore, the principle is demonstrated more delightfully by placing the common center of gravity of the apparatus outside the earth-globe, whereas strict astronomical scale would require it to lie inside the larger globe.

DEPARTMENT OF PHYSICS, HAVERFORD COLLEGE, HAVERFORD, PENNSYLVANIA.

The Solar Eclipse of 1938 May 29— the First Umbral Eclipse of its Saros Series

By ALEXANDER POGO

If, during an eclipse season, the relative position of the full and of the new moon with respect to the nodes is such that the full moon occurs near the ecliptic limits of totality while the new moon occurs near the umbral ecliptic limits, a total eclipse of the moon separated by an interval of fifteen days from an umbral eclipse of the sun may occur. The month of May, 1938, offers us an example of such an eclipse season: a total eclipse of the moon will occur on May 14; half a lunation later, on May 29, a total eclipse of the sun will take place. The eclipse of May 14 will be the last total eclipse of the lunar saros series L42; the eclipse of May 29 will be the first total eclipse of the solar saros series S43. The umbral run of the lunar saros series L42—see the middle row in Figure 1—consists of 7 initial partial, 25 total, and 7 terminal partial eclipses; these 39

eclipses have the distinction of forming the shortest of the 81 complete lunar umbral runs within the limits of Oppolzer's *Canon;* we shall return to the lunar saros series L42 in a forthcoming paper.

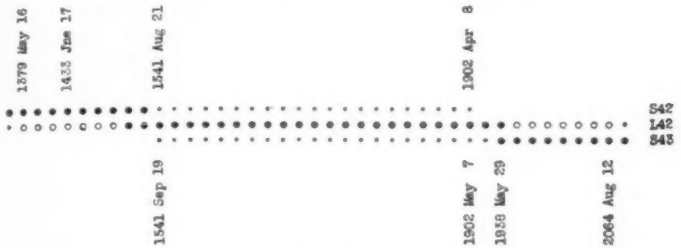


FIGURE 1

TRANSITION FROM SERIES S42 TO SERIES S43

Upper row: the 21 terminal penumbral eclipses of the solar saros series S42, preceded by the end of the umbral run of the series.

Middle row: the 39 umbral eclipses (7 initial partial, 25 total, 7 terminal partial) of the lunar saros series L42, preceded by the last initial penumbral and followed by the first terminal penumbral eclipse of the series.

Lower row: the 22 initial penumbral eclipses of the solar saros series S43, followed by the beginning of the umbral run of the series.

The total solar eclipse of 1938 May 29 will have a wide but short path of totality, in the South Atlantic, sweeping over the South Orkneys, South Georgia, and some of the South Sandwich Islands; as a partial eclipse, it will be visible in the southern half of South America and in South Africa. From a heliophysical point of view, the eclipse of 1938 May 29 is of little importance; the very fact, however, that its total phase is observable is worth pointing out, because it will be the first umbral eclipse in its saros series.

The number of saros series running simultaneously, i.e., the number of eclipses which occur during 18 consecutive years, is decreasing since the end of the XVIIIth century. Tables I and II illustrate the fact that, during the XIXth and XXth centuries, the number of umbral solar runs coming to an end exceeds the number of newly added umbral solar runs; incidentally, if Table I were extended into neighboring centuries, the saros series listed in its first column would exhibit such intervals as 47 or 6 lunations, as in the case of the first column of Table II; we shall return to these and cognate matters in a forthcoming paper.

On May 29, 1938, for the third time since 1797 June 24, the first eclipse of a new umbral solar run will occur—a rather rare event in these centuries of "recession" in saros-series activity. The eclipse of 1938 May 29 will, moreover, be a total eclipse with a noon point of centrality—a very rare event, since most of the eclipses at the beginning or at the end of an umbral solar run exhibit the characteristics listed in Tables I and II; a total eclipse with a noon point of centrality did not

occur at the beginning or at the end of an umbral solar run since 1646 July 12, when the umbral run of series S1 came to an end (the last eclipse of the penumbral run of series S1 occurred on January 5, 1935).

The eclipse of 1938 May 29 will be the 23rd eclipse of the solar saros series S43; the first penumbral eclipse of the series occurred on September 19, 1541. It might be pointed out, for the benefit of those archaeologists who believe that partial solar eclipses cannot be seen in the tropics, that the last four eclipses of the initial penumbral run of series S43,

1866 Apr. 15	maximum phase:	0.664
1884 Apr. 25	" "	0.754
1902 May 7	" "	0.858
1920 May 18	" "	0.973.

were visible in the tropics; we shall deal with these eclipses in a forthcoming paper devoted to the eclipse of 1938 November 21 and the penumbral run of the solar saros series S49.

The transition from series S42 to series S43 is illustrated by the upper and lower rows of Figure 1. For the benefit of those historians who believe that partial solar eclipses deserve little attention, especially when they occur in high latitudes, it might be pointed out that the eclipses of the terminal penumbral run of series S42 remained visible in inhabited regions to the very end of the series:

1866 March 16	max. phase:	0.210	visible in NE Asia
1884 March 27	" "	0.141	" " N Europe
1902 April 8	" "	0.065	" " NW Canada

The umbral run of series S42 contained several remarkable eclipses. The eclipse of 1433 June 17 was long remembered in Scotland as the Black Hour. According to the maps in Schroeter's *Spezieller Kanon*, southern Portugal, including the city of Lisbon, was within the tracks of totality during the eclipse of 1379 May 16 and again, 36 years later, dur-

TABLE I

SOLAR ECLIPSES BEGINNING UMBRAL RUNS IN THE XIXTH AND XXTH CENTURIES

Saros series	Date	Characteristics
S219	1880 July 7	annular; central; noon
S131	1891 June 6	ann.-total; central; midnight
S43	1938 May 29	total; central; noon
S184	1967 Nov. 2	total; non-central; sunrise

TABLE II

SOLAR ECLIPSES ENDING UMBRAL RUNS IN THE XIXTH AND XXTH CENTURIES

Saros series	Date	Characteristics
S95	1816 May 27	annular; central; noon
S7	1845 May 6	annular; central; sunrise
S148	1874 Oct. 10	annular; central; sunset
S142	1928 May 19	total; non-central; sunset
S60	1939 Oct. 12	total; central; sunrise
S189	1950 Mar. 18	annular; non-central; sunset
S54	1957 Apr. 29	annular; non-central; sunrise
S107	1979 Aug. 22	annular; central; noon
S195	1986 Oct. 3	total; central; sunset

ing the eclipse of 1415 June 7. Similarly, according to Schroeter's maps, the region of Iceland just south of Reykjavik was within the tracks of totality during the Black-Hour eclipse of 1433 June 17 and again, two saroses later, during the eclipse of 1469 July 9. To appreciate a return of a total eclipse to the same city within the lifetime of a generation, the case of London might be quoted which remained outside the tracks of total solar eclipses between 878 October 29 and 1715 May 3.

CARNEGIE INSTITUTION
WASHINGTON, D. C.

The 1937 Opposition of Mars

By ROBERT BARKER*

The opposition of 1937 was remarkable in a very important way. Despite the planet's low declination, very fine seeing was obtained at my observing station at Cheshunt, Herts, England, generally on clear nights following much rain, when very steady and transparent seeing conditions prevailed. It is known that this happy condition did not apply to several stations in England where keen Martian observers reside, and it may be that 1937 will, on the whole, afford very meagre results. My telescope is a 12.6-inch Calver equatorial, clockdriven reflector, focal length 120 inches, an excellent instrument for detailed lunar and planetary work. Powers employed were: Browning achromatic ×315, a Doll solid ocular made on the Tolles principle ×360, Horne and Thornthwaite negative ×420.

As in 1935, the North Pole was well tilted earthwards, and Mars' blue-green equatorial and south tropical regions were presented high S. on disc just within the limit of *definite* seeing. The North Polar Cap was small, with few exceptions; hazy and not generally well defined, the greatest exception being on July 17 when Mars was occulted by Moon.

Sometimes when "canali" and maria showed clearly, the N.P.C. was almost lost in a luminous haze that so often prevailed in the N.P. regions. The S. tropical maria and regions were often very clearly outlined, their general tone being a pronounced blue green. Certain areas were flecked or chequered with considerable patches of white, indefinite in exact outline, but very distinct in their combined contrast and effect. The thin strip of Sinus Sabæus on June 6, 7, 8, 11, 13, and July 17, seemed almost divided by these white fields; the Margaritifer especially was traversed by a white streak extending across M. Erythræum. The other maria exhibited the usual light chequering seen at every opposition, and Hellas gleamed (like a huge S.P.C.) across the S. limb when longitude was favorable. The dividing lighter gaps of Atlantis and Hesperia afforded sharp contrasts on June 20; Atlantis was very white and even, while Hesperia was darker and broken. M. Sirenum was too near S. limb for

*Fellow of the Royal Astronomical Society.

easy observation, but on June 29 the familiar Beak of the Sirens was seen, tailing off into the Araxes canal.

The narrow dark streak of Pandore Fretum, though very high S., was distinctly seen, dividing the light areas of Pyrrhœ and Deucalionis regions; and the Furca (directly N. of Pandore) which marks longitude 0°, was sometimes seen joined to Margaritifer by the semi-dusky Iani Fretum. The varying tones that prevail in Mars' tropical areas are distinct and puzzling, and their significance may never be fully understood, though they hint at profuse vegetation subject to seasonal influence.

The tropical regions 40° each side of zero longitude, are the most complex and beautiful features the planet presents; S. of equator are 3 narrow strips bounding 2 enclosed white regions, and N. is the area of well marked, well known canals nearly always prominent at each opposition.

Syrtis Major is the easiest object (plainly seen in a 3-inch refractor) and this feature was well placed, running from equator N. to the 30th parallel. Very dark, almost black, and lightened by the white fields that dotted its area, this splendid region dominated the clear Martian disc when central meridian was near 295°. M. Acidalium in N. temperate zone is generally as dark as Syrtis, but this great northern "sea" was always more or less veiled during 1937, all areas N. of 50° N. lat. to the polar cap being ill defined. The Propontis was sometimes quite difficult to recognize and outline; and Casius, though always assuming its tapering form, was sometimes veiled.

Of the canals Lowell writes: "Good air is essential to their detection . . . size of aperture of the telescope used is a very secondary matter . . . it is not simply question of a clear air but of a steady one . . . for the canals to come out in all their fineness and geometrical precision, an atmosphere possessing moments of really distinct vision is imperative . . . no one who has not seen the planet thus can pass upon the character of these lines."

Many canals appeared clear cut and quite definite, Gihon was distinct, often easy, but on June 8 Gihon was rivalled and beaten by Djihoun. I find in my notebook "Oxus intensely marked." Later, by July 17, Djihoun faded, but this presentation was unforgettable and was witnessed by my younger son who easily recorded these two great canals.

Reference to the chart will show many well-known canals, all were seen more than once before inclusion, and their positions checked beyond doubt. The reduction of 17 drawings on a spherical projection to Mercator's projection was not easy (Figure 1), and I agree with Lowell who says, "Mercator's projection I take to have been primarily an invention of the devil, although commonly credited to Mercator. It is intended for those at sea, whom we pray for on Sundays. It is certainly calculated to put anyone entirely at sea who attempts to learn geography by means of it."

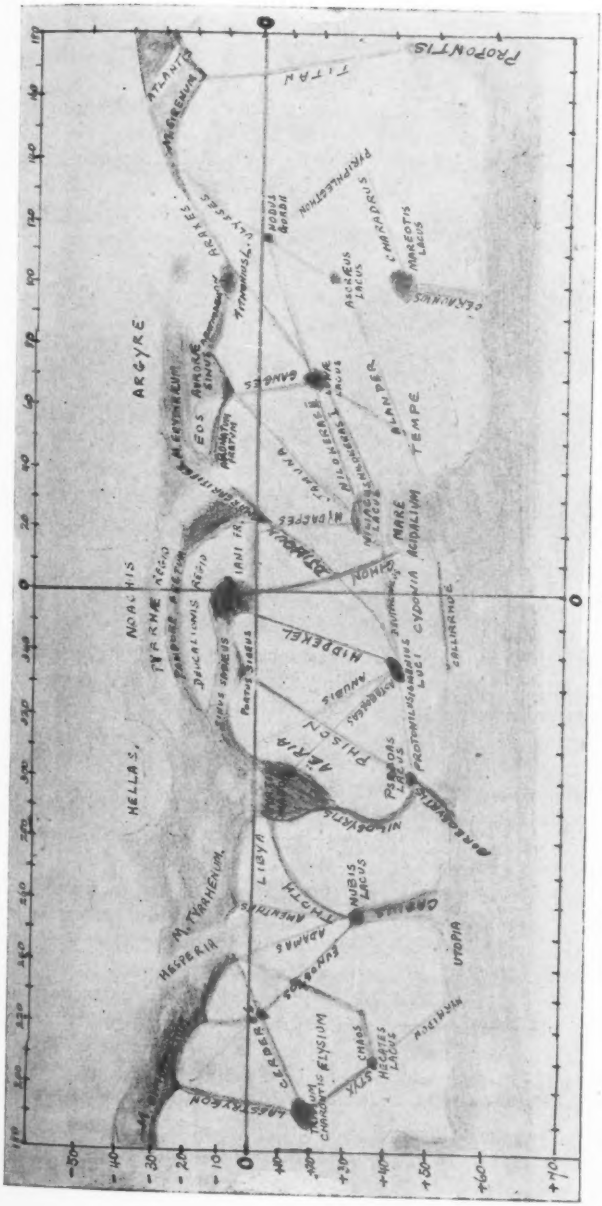


FIGURE 1
CHART OF MARS IN 1937
(North at bottom, East at right)

Charts on Mercator's projection are generally marked areographic W on right, and areographic E on left. This custom is not followed on accompanying chart, in order to agree with the usual orientation of the three small drawings.

These notes from Mr. B. Burrell (one of our finest English observers) of Doncaster, Yorks, come to hand: Pandore Fretum always distinct, Gihon easy, and Indus strong, Oxus seen. Acidalium not so dark as in 1935. Luna L. diffuse, Nilokeras I and II seen easily. Propontis and Trivum Charontis rather faint. M. Cimmerium and M. Tyrrhenum dark. Syrtis very dark, Casius lightly shaded and indefinite. Furca, very dark spot, not divided. N.P.C. usually very indistinct.

The 3 small drawings (Figure 2) were traced from my notebook, ex-

FIGURE 2
DRAWINGS OF MARS IN 1937
(North at bottom, East at right)

actly as I drew them at the eyepiece. I never alter, or correct these drawings, as I make them, so they remain, although positional errors are sometimes noticed afterwards.

In the drawing on the left, made on June 8 with central meridian 0°, N.P.C. is very small, Acidalium faint and misty. Djihoun is intensely marked and easily held; also Deuteronilus. Ismenius Luci, elongated and dark. Protonilus, seen N.W. Astaboreas (N.W.), seen for first time. Cydonia R (W of Acidalium), very bright. Hiddekel and Sitacus, plainly glimpsed.

In the middle drawing, made on June 15 with central meridian 295°, Syrtis appears very dark with light patches. Pseboas Lacus, veiled. Casius, tapering and not dark. Libya R, distinct. Thoth, very distinct. Nilo Syrtis, easy. N.P.C., scarcely visible.

In the drawing on the right, made on June 20 with central meridian 243°, the sky clear after heavy rain, Mare Tyrrhenum was intensely vivid. M. Cimmerium, dark with Cerberus strongly marked. Trivium Charontis, darkly distinct and hazy. Nubis L., prominent. Adamas, glimpsed and Styx (W) with Hecates L. mark Elysium. Lybia (S.E.) very distinct. Hesperia, dark and broken. Atlantis, bright.

So appeared Mars to an amateur whose study of this fascinating, and perhaps mysterious, planet has always been a source of infinite delight.

Fragmentary Notes on Astronomy in Japan

By YASUAKI IBA

(Part V)*

METEOR SHOWERS CHRONICLED IN THE FAR EAST

The Identification of Leonids in the Old Annals

The Leonids in 1932 seemed to have gone astray, contrary to the expectation of the astronomical interests worldwide. In reading through, however, the records en bloc which are said to be of Leonids, in Japan, Korea, and China where the apparitions were better or more frequently recorded as compared with European countries, especially ere 17th Century, statistics derived during interval from A.D. 902 to 1901 indicate that the periods of Leonids were, in a popular sense of word, not so punctual as astronomically worked out: chronologically speaking on many occasions there occurred certain retrogression or precession.

That this leads one to incline toward an inference that the Leonids expected last year [1932] may demonstrate their sparkling grandeur within a year or two can not be regarded totally groundless.

Prof. Dr. K. Hirayama published his paper in Vol. 5, No. 6, 1912, *The Astronomical Herald,* titled "Historical Records of the Leonids," gist of which was transcribed, as widely known, in the "Observatory."

It has recently been supplemented by Messrs. S. Kanda and Susumu Imoto: thus chronologically 18 apparitions can be identified with the annals in 26 years. Astronomically speaking the foregoing does not mean, platitudinous to assure, the totals, revealing the fact that during the said interval 13 apparitions are not traced thus far in any annal.

With view to economize the space and also with belief that records on Leonids in occidental countries are already in the hands of readers, they were abbreviated. Dates converted are Gregorian.

Contents of the Records

YEAR	COUNTRY	REFERENCE
902 (X.23)[1]	Spain	Quetelet. Condé, Histoire de la domination des Maures en Espagne
931-4	Italy	Quetelet. Muratori, Rerum Italiarum Scriptores
931	China	Chiu Wu Tai Shih T'ien Wên Chich

On Ping Hsü 9th Moon, 2nd year of Chang Hsing, i.e., 931, X. 20, after 5 beat of drum till twilight witnessed small meteors over hundred, shooting hither and thither in all directions in the sky.

*Parts I, II, III, and IV appeared in May, 1934, June-July, 1937, February, 1938, and March, 1938, issues, respectively.

[1][Evidently, tenth month, twenty-third day, October 23.]

YEAR	COUNTRY	REFERENCE
	China	Wu Tai Shih Ssu Wên K'ao

On Ping Hsü, 9th Moon, 2nd year of Chang Hsing many stars shot hither and thither. On Ting Hai, i.e., X. 21, many stars shot here and there and precipitated.

934	Manchuria	Liao Shih

On Keng Tsu, 9th Moon, 9th year of T'ien Hsien, i.e., X. 18., stars precipitated like raining in south west.

	China	Wu Tai Shih Ssu Wên K'ao

On Hsin Ch'ou, 9th Moon, 1st year of Ch'ing T'ai, i.e., 934 X. 19, many stars shot hither and thither.

	China	Chiu Wu Tai Shih Pên Chi

At night on Hsin Ch'ou, 9th Moon, 1st year of Ch'ing T'ai, i.e., X. 19, a star as big as a measuring box shot to south west, with trail of several Chang (10 ft.), curling as the shape of dragon, and too many meteors shot to calculate.

967	Japan	Fusoh Riakuki

At night on 9th, 9th Moon, 4th year of Koh Ho, i.e., X. 19, from 10 p.m. stars begin to shoot, east to west, incessantly till 4 a.m., resembling as if swords glittering.

	Japan	Nihon Kiriaku

At 10 p.m. on 9th, 9th Moon, 4th year of Koh Ho, meteors appeared as luminous as the moon-light, shooting from N.E. to S.W. Stars in the west were in disorder and meteoric shooting lasted all night. On 13th, i.e., X. 23 Imperial ordinance was issued for universal amnesty, releasing even those who could not be franchised (those sentenced to death?). The amnesty was due to anomalism of meteors.

	Japan	Ninjukagami

On 9th, 9th Moon, 4th year of Koh Ho, meteors were witnessed at night. Great anomalism.

1002	Japan	Nihon Kiriaku

On 6th, 9th Moon, 4th year of Choh Ho, i.e., 1002 X. 20, observed meteor shooting throughout the night. On 7th witnessed meteor shooting from 10 p.m. to 4 a.m.

	China	Sung Shih T'ien Wên Chih

On Hsin Ssu, 8th Moon, 5th year of Hsien Ping, i.e., X. 3, a star was observed in the sidereal division of Ying Shih (west part of Pegasus) presenting white color. On Ping Shên, i.e., X. 18, star, as big as Tou, shot westward, thence to S.W., giving out a sound like ox snarling, with scores of small stars in its wake which precipitated. (Note: Tou is a measuring box.)

	Japan	Honchoh Seiki

On the night of 7th, 9th Moon, 4th year of Choh Ho, i.e., X. 21, there was celestial anomalism, viz., observed meteors from midnight till 4 a.m., as in 4th year of Koh Ho.
On 8th Imperial Rescript was read in the presence of Sadaijin (Minister, next to the Premier) and other officials, because of meteors on 7th.

1035	Japan	Nihon Kiriaku

Witnessed meteors on the night of 11th, 9th Moon, in 8th year of Chohgen, i.e., 1035 X. 20. On 20th in accord with Imperial Rescript amnesty was promulgated on account of celestial anomalism, by which all criminals below Taiheki (title of crime) and those who could never be franchised, were exempted from corporal punishment. On 23rd gifts were respectfully donated to 21

YEAR	COUNTRY	REFERENCE
	Shrines, due to celestial anomalism. Nioh Ye (a party for praying) was held on 26th, because of meteoric apparition.	
	Japan	Fusoh Riakuki
	At 4 a.m. on 11th, 9th Moon, 8th year of Chohgen, there occurred meteoric anomalism. On this account universal amnesty was promulgated on 20th.	
1037	Japan	Hiaku Renshoh
	On 3rd, 9th Moon, 1st year of Chohreki, i.e., X. 20, stars precipitated at random, shooting in all directions, horrifying the folks.	
	Japan	Fusoh Riakuki
	On 3rd, 9th Moon, 1st year of Chohreki there was a meteoric anomalism at midnight.	
	Japan	Yukichikaki
	On the eve of 4th, 9th Moon, 1st year of Chohreki, meteoric anomalism occurred. This day, 16th, amnesty was declared because of foregoing. On 22nd, 10th Moon, Nioh Ye was held at eight Administrative Departments, in which H.I.M., The Emperor, participated.	
1101		Chron. S. Maxentii
1202	Egypt	Quetelet
	Russia	J.B.A.A., Vol. 33
1237	Japan	Azumakagami
	At dawn on 29th, 9th Moon, 3rd year of Katei, i.e., 1237 X. 26, observed luminous objects that were called meteors. Praying Party was held on 4th, 10th Moon, because of celestial anomalism.	
1238	Japan	Azumakagami
	From 10 p.m. to 2 a.m., 9th Moon, 1st year of Rekinin, i.e., X. 25, witnessed meteors, countless in number, leaving trails behind 3 or 4 ft., some 7 or 8 ft., presenting whitish and red colors.	
1366	Austria	Quetelet
1466	Japan	Gohohkohinki
	13th, 9th Moon, 1st year of Bunsei, i.e., X. 31. Fine weather. Heard on 17th that on 13th instant there were meteors after midnight, emerging from N.E. toward S.W., like last year, however no scintillation. The time, date, and month were same as in last year. It was very anomalous occurrence.	
	Japan	Ohnin Kohki
	Again in next year, viz., on 13th, 9th Moon, 1st year of Bunsei, (X. 31) luminous objects appeared at precisely same 10 o'clock, shooting from N to NW with clangorous shocks. Twice noticed rumbling sounds altogether, creating sensation among populace. It was celestial anomalism called Tengu Riusei.	
	(Note: Tengu is a name given to an imaginary being with tremendously long nose and wings and supposed to be with miraculous power, plying to and fro, always soaring in the heaven. According to Mr. Kanda great meteors were called in these days Tengu Riusei.)	
1532	Japan (Korean)	Zohho Bunken Biko
	At night Hsin Wei, 9th Moon, 27th year of Chuso, i.e., 1532 XI. 3, witnessed stars falling like raining.	

YEAR	COUNTRY	REFERENCE
	Japan (Korean)	Ressei Jitsuroku

At night on Hsin Wei (i.e., November 3rd), 9th Moon, Jên Ch'ên, 27th year of Chuso, thrice observed meteors shooting like shower. At night on Jên Shên, meteors were witnessed thrice.

1533 Japan — Kuge Bunin

At daybreak on 8th, 10th Moon, 2nd year of Tenmon, i.e., XI. 4, observed stars falling like snow in the S.W.

Japan — Kohnendai Shiki and others

On 8th, 10th Moon, 2nd year of Tenmon, observed shooting stars filling the half of celestial cupola and precipitating to the land and sea.

Japan — Bunin Bunrui and Nokori Taiheiki

On 8th, 10th Moon, 2nd year of Tenmon, no cloud but thunder. At daybreak witnessed stars shooting, covering half of the heaven and precipitating with rumbling as that of thunder.

Japan — Nihon Nendaiki

At dawn on 8th, 10th Moon, 2nd year of Tenmon in the reign of Gonara Tenno, (H.I.M., The Emperor, The 105th) witnessed stars shooting, permeating one half of the heaven and precipitating.

Japan — Wakan Nenpioroku and Hayabiki-Nenreki Tsuran

On 8th, 10th Moon, 2nd year of Tenmon, observed thousands of stars shooting in almost half of the heaven.

Japan — Wakan Nenrekisen

In 10th Moon, observed quite lot of stars falling.

Japan — Ashikaga Kiseiki

At twilight on 8th, 10th Moon, 2nd year of Tenmon, stars dazzlingly scintillated all over the heaven and shot down to the land and sea, breaking into pieces like stones and giving out tremendous clangours, entailing the rumor to the effect that the earth might be again knocked about by some anomalism and also that the total decay of the kingdom would be imminent and populace awfully lamented in dismay.

Japan (Korean) — Zohho Bunkenbikoh

On Ping Tsu, 10th Moon, 28th year of Chuso, i.e., 1533 XI. 3, meteors and flying stars were at rampant in all directions like raining.

China — Ming Shih T'ien Wên Chih

From 4 Koh till 5 Koh on Ping Tsu, 9th Moon, 12th year of Chia Tsing, i.e., XI. 3, witnessed countless meteors, big and small, shooting hither and thither in all directions. It evanesced by twilight. (Note: Ping Tsu not identified in 9th Moon. Should be in 10th Moon, and XI. 3.)

Japan (Korean) — Ressei Jitsuroku

At 3 Koh, on Ping Tsu, 10th Moon, i.e., November 3rd, 28th year of Chuso atmospheric phenomenon, composing of bluish, yellowish, and whitish colors, broke out in the environs of Bunsho Sei with its tail pointing Ohrio Sei (Cassiopeia) appearing as if two bundles of cotton fabrics in pair and its shape as that of dragon. After a while it evanesced. Meteors appeared 9 times, shooting in all directions like shower. Angles of stars through which meteors shot were unable to measure. They precipitated like raining.

YEAR	COUNTRY	REFERENCE

Meteoric apparition occurred 4 times at 2, 3, 4, and 5 Koh on the night of Ting Wei.

China — Wên Hsien T'ung K'ao

On Hsin Ssu, 10th Moon, i.e., November 8th, 12th year of Chia Ching, stars precipitated like raining.

1566 Japan (Korean) — Zohho Bunkenbikoh

On Hsin Wei, 10th Moon, 21st year of Meisoh, i.e., 1566 XI. 5, again as on that occasion. (Note: By "again as on that occasion" it means the record for meteoric apparition 6 years preceding, i.e., in 1560, which reads: "On Ting Yu, 8th Moon, (Keng Shên), 15th year of Meisoh observed stars flying and shooting like raining in all directions.")

1602 China — Ming Shih T'ien Wên Chih

On Hsin Ssu, 9th Moon, 30th year of Wan Li, i.e., 1602 XI. 6, witnessed hundreds of stars, big and small, which shot hither and thither.

Another apparition of Leonids has been identified anew by Mr. Shigeru Kanda, of Tokio Astronomical Observatory, in Chinese annals, viz., that of 1666, sent to him last month by Mr. Itaru Imai, of The Eastern Civilization Research Institute in Shanghai.

This minimizes 13 non-apparitions to 12, in other words increases 18 apparitions to 19; thus lament of Prof. Dr. Willard J. Fisher, viz., "Still more gaps to be filled" can be mollified to some extent.

1666 China — T'ien Wên K'ao Ku Lu

At 4 Koh, 11th, 10th Moon, (i.e., November 8th) 5th year of K'ang Hsi, Ch'ing Dynasty, a gigantic star was observed in the South East, accompanying numerous small stars in its wake, that shot up and down, and or, right and left. The huge star precipitated, followed by the small stars.

SUMMARY

Year	Country	Year	Country
902 C	Ispania	1466	Japan
{ 931	Italy and China	O	
{ 934 C	Manchuria and China	{ 1532 C	Japan
967 C	Japan	{ 1533 C	Japan, Russia, and China
1002 C	Japan and China	1566 C	Japan
{ 1035	Japan	1602	China
{ 1037 C	Japan	O	
O		O	
1101	Unknown	1698	Switzerland
O		O	
O		O	
1202	Egypt and Russia	1799 C	Europe and U.S.A.
{ 1237	Japan	{ 1832	Europe and U.S.A.
{ 1238	Japan	{ 1833 C	U.S.A.
O		{ 1866	England
O		{ 1867	Europe and U.S.A.
O		1868	Europe and U.S.A.
1366	Austria	{ 1898	Europe and U.S.A.
O		{ 1901	Europe and U.S.A.
O			

"O" indicates apparition not traced. "C" indicates apparition conspicuous.

(To be continued)

Planet Notes for June, 1938

By R. S. ZUG

Note: Greenwich Civil Time is employed, unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours; Central Standard Time, 6 hours; etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephmeris and Nautical Almanac.*

Sun. The positions of the sun for June 1 and June 30, respectively, are: $\alpha = 4^h\ 32^m.8$, $\delta = +21°\ 56'.0$; $\alpha = 6^h\ 32^m.8$, $\delta = +23°\ 13'.8$. The sun's motion along the ecliptic is in a predominantly eastern direction during June. On June 21 the sun leaves the constellation Taurus and enters the constellation Gemini. The summer solstice is reached June 22, 2^h, which event inaugurates the summer season. Upon reaching the summer solstice the sun attains its most northerly declination of the year, i.e., +25° 26′ 45″.9. Values for the equation of time are as follows:

Date 1938	Equation of Time (Mean - Apparent) m s	Date 1938	Equation of Time (Mean - Apparent) m s
June 1	−2 29	June 17	+0 29
5	−1 51	21	+1 21
9	−1 7	25	+2 13
13	−0 21	29	+3 4

Moon. Phenomena of the moon will occur as follows:

		h	m
First Quarter	June 5	4	32
Full Moon	12	23	47
Last Quarter	21	1	52
New Moon	27	21	10
Perigee	May 30	17	
Apogee	June 14	18	
Perigee	28	1	

Mercury. The planet Mercury will be in superior conjunction on June 22. It is poorly placed for observation during June.

Venus. Venus is gradually moving eastward with respect to the sun, and is thereby becoming more conspicuous as an evening star. On June 30 its altitude at time of sunset will be about 21°. The stellar magnitude of the planet is still −3.4. The apparent angular diameter of the planetary disk will be 13″.8 on July 1, while the distance from the earth on the same date will be 113.6 million miles. The planetary disk will appear 78 per cent illuminated on July 1.

Mars. June 1 finds Mars only 17° east of the sun and inconspicuous in the last rays of the setting sun. Its apparent diameter on this day is only 3″.7, not far from the minimum attainable, and its distance from the earth, 235.6 million miles. The planet is of interest at this time chiefly to those wishing to follow it as long as possible as it nears conjunction with the sun.

Jupiter. Jupiter rises about an hour before midnight during June, about 15° south of the east point. It is a conspicuous morning star, reaching the meridian by sunrise. Its meridian altitude on June 30 is 33°. Jupiter's easterly apparent motion among the stars ceases on June 22, when the motion of the planet becomes retrograde. The stellar magnitude of Jupiter during June is about −2.1.

Saturn. Saturn rises 2 hours before the sun on June 1, and 4 hours before the sun on June 30. By the end of June, therefore, it will be well situated for ob-

servation in the morning sky. It will be found in the constellation Pisces, and about 4° north of the celestial equator. The stellar magnitude of the planet is +0.9. The rings are beginning to open up again and at present are about six times as long as they are wide. On June 15, the major and minor axes of the outer ellipse of the outer ring, and the angular polar diameter of the planet itself, will be, respectively, 38″.3, 6″.9, and 15″.2. The southern surface of the rings is now visible.

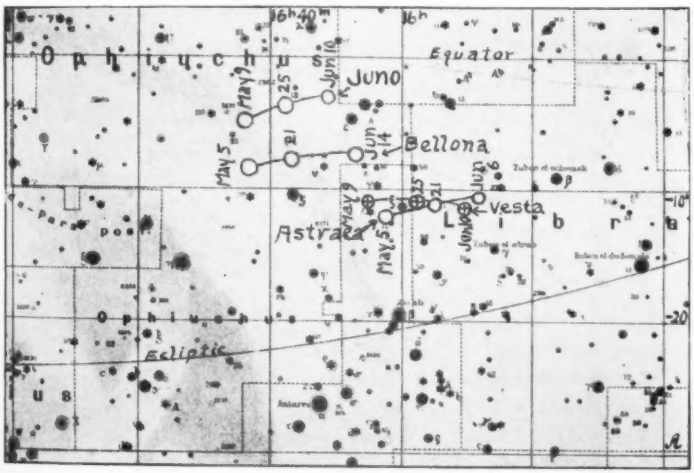
Uranus. Uranus is now in the morning sky and by June 30 will be 3½ hours from the sun. Its position on June 30, 0^h, will be, $\alpha = 2^h\ 57^m\ 2^s$, $\delta = +16°\ 27'\ 20''$. The daily motion in right ascension and declination, respectively, is on June 15, +9^s.8, and +41″.

Neptune. Neptune is in quadrature with the sun on June 9, 22^h, and is well placed for early evening observation. In *Planet Notes* for March, 1938, a map of the star field surrounding Neptune is reproduced, and upon it the path of Neptune from month to month is plotted. The chart is arranged for convenient use with an inverting telescope, and it is hoped that it will facilitate the efforts of amateur astronomers in locating and identifying Neptune.

Asteroid Notes

By HUGH S. RICE

The minor planet Vesta is just visible to the naked eye at this time under perfect conditions of seeing. Its magnitude changes from 6.0 to 5.9 during the period of this issue. We have plotted its apparent course on *Schurig's Himmelsatlas.*



This chart is on a much smaller scale than that which one should ordinarily use for asteroids, as the other asteroids besides Vesta are fainter than the faintest stars of the chart. However, it will be a fair guide to the location of the objects. The dark areas represent the Milky Way.

Crossing Vesta's apparent path is the course of asteroid 5 Astraea, which is of magnitude 9.9. Planet 3 Juno will also be found, with magnitude 10.0. Besides these, 28 Bellona, still fainter (10M.4), is likewise plotted.

Users of reflectors are interested in the positions of asteroids such as the following: 185, which is in the constellation Herculis, and 65, in Ophiuchus. The places were computed at the German asteroid headquarters, the Astronomisches Rechen-Institut at Berlin-Dahlem.

EPHEMERIDES OF ASTEROIDS. FOR 0h U.T. EQUINOX OF 1950.

		185 EUNIKE (10M.5) α h m	δ ° ′			65 CYBELE (10M.3) α h m	δ ° ′
May	14	16 39.7	+12 16	May	14	16 53.0	−17 22
	22	16 33.5	12 52		22	16 47.6	17 8
	30	16 26.9	13 13		30	16 41.7	16 54
June	7	16 20.2	13 16	June	7	16 35.6	16 42
	15	16 14.0	13 1		15	16 29.7	16 33
	23	16 8.5	+12 31		23	16 24.5	−16 27

Hayden Planetarium, American Museum of Natural History,
New York City, April 21, 1938.

Occultation Predictions

(Taken from the *American Ephemeris*)

Date 1938		Star	Mag.	IMMERSION Greenwich C.T. h m	a m	b m	Angle E from N °	EMERSION Greenwich C.T. h m	a m	b m	Angle E from N °
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′.											
June	1	110 B.Gem	6.2	1 14.6	+0.7	−2.8	164	1 40.5	−0.3	0.0	225
	5	237 B.Leo	6.3	3 37.7	−0.6	−0.7	63	4 16.5	0.0	−2.6	342
	9	40 H.Vir	5.1	3 44.7	−1.5	−2.1	144	4 48.7	−1.4	−0.8	249
	11	10 G.Sco	5.9	6 43.2	−1.3	−1.7	113	7 51.2	−0.5	−0.9	249
	15	*d* Sgr	5.0	3 33.9	−1.5	+1.6	75	4 58.9	−1.9	+0.8	266
	18	c^1 Cap	5.3	7 2.6	..	..	140	7 19.6	..	..	165
OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′.											
June	5	237 B.Leo	6.3	3 21.9	−1.2	−1.0	83	4 19.1	−0.4	−2.4	328
	5	55 Leo	6.0	5 25.6	−0.4	0.0	51	5 54.1	0.0	−3.2	352
	9	40 H.Vir	5.1	3 25.0	..	..	169	4 12.3	..	..	235
	11	10 G.Sco	5.9	6 14.6	−2.0	−1.1	108	7 36.7	−1.4	−0.9	259
	15	*d* Sgr	5.0	3 11.2	−0.6	+1.4	91	4 25.1	−1.2	+1.4	258
	18	c^1 Cap	5.3	6 21.6	−1.4	+0.2	124	7 3.1	−0.9	+3.5	190
	20	22 B.Psc	6.5	10 20.1	..	..	132	10 43.2	..	..	165
OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′.											
June	2	30 B.Cnc	6.1	4 11.4	−0.7	−0.7	75	4 57.4	+0.2	−2.2	327
	3	κ Cnc	5.1	4 11.2	..	..	27	4 16.5	..	..	22
	5	237 B.Leo	6.3	2 40.7	−1.6	−1.6	130	4 0.4	−1.7	−1.5	292
	5	55 Leo	6.0	4 58.3	−1.5	−0.9	87	5 59.6	−0.6	−2.5	327
	11	10 G.Sco	5.9	5 17.3	−1.7	−0.8	132	6 38.7	−2.7	+0.5	254
	19	207 B.Aqr	6.4	12 28.1	−2.5	+0.6	81	13 49.8	−1.3	+1.7	214
	20	22 B.Psc	6.5	9 16.6	−1.0	+1.2	95	10 17.8	−0.8	+2.5	212
	20	9 Psc	6.4	12 20.1	−1.2	+2.5	29	13 37.2	−2.6	+0.1	266

The quantities in the columns a and b are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under a for the star to be observed; similarly, with the latitude, using b; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Comet Notes

By G. VAN BIESBROECK

We enter the fifth month of the year without any comets known to be observable. The search for PERIODIC COMET 1927 VI (GALE) should be continued: according to the elements by Sumner this comet passed perihelion on April 19 but there is considerable uncertainty about that date. The theoretical brightness is maximum in the beginning of May so this is the best time to recover the object, which should be looked for in the morning sky as seen from the following ephemeris, continued from p. 210. We also continue the ephemeris of COMET 1925 II (SCHWASSMANN-WACHMANN). I have looked several times for that object in April without finding it. The position is quite safely established by the computation of the Reverend Mr. Behrens, hence the comet is fainter than 15th or 16th magnitude. From past experience we know that it can brighten up quite suddenly so it is well worth while to watch the region.

	Comet Schwassmann-Wachmann		Comet Gale	
	α	δ	α	δ
1938	h m	° ′	h m	° ′
May 6	15 37.7	−31 0	23 4.3	−14 38
14	33.8	30 51	23 32.3	12 50
22	29.9	30 38	23 58.0	11 5
30	26.1	30 23	0 21.3	9 26
June 7	22.4	30 6	0 42.3	7 56
15	19.2	29 47	1 1.2	6 36
23	16.5	29 28	1 18.0	5 28
July 1	15 14.4	−29 9	1 32.7	− 4 33

Williams Bay, Wisconsin, April 20, 1938.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

As nothing of special interest has been reported of late except a few fireballs, not yet worked up, I have decided to publish results on several of previous years.

Part I consists of five cases worked up by F. W. Smith while acting as a volunteer member of our staff. The cases were not particularly favorable ones and he derived all the usable data that were to be had. The calculations were wholly made by him, and the section should more properly be signed with his name. Part II consists of a digest of a very complete paper on the Missouri-Illinois fireball of 1934 August 11, by J. W. Simpson. Part III consists of results on a splendid fireball observed in Oregon. There is every reason to believe meteorites were pro-

duced by this object and I believe the end point is well determined. It is further interesting as proving that a long-enduring train for such a large object, as for instance in the case of the famous fireball of 1933 March 24 over Texas-Oklahoma-New Mexico, is not limited to the stratum determined by Trowbridge for the night cases he investigated, but apparently merges into what was formerly called the "smoke-train" of daylight fireballs, so that the train may be quite continuous down to the point of explosion or disappearance. The further discussion of this will not be undertaken here, as I am at work on the whole subject of long-enduring trains and do not wish to anticipate conclusions.

While speaking of the 1933 March 24 fireball, recently my attention was called by Mr. Fletcher Watson to the inclination of the orbit as published by me.* On looking this up, it was found that two figures in the right ascension of the radiant had been interchanged on the computing sheet, in copying, making the elements erroneous but not affecting the rest of the results. The corrected elements are: $L = 27°.6$; $\pi = 60°.2$; $\Omega = 3°.4$; $q = 0.28$.

As the summer months are approaching, it is well to call attention to the desirability of increased summer activity on the part of all our members. The formation of groups for simultaneous observations on meteors, to determine heights, are specially recommended. I will be glad to have plans submitted to me by those who need guidance in such work, and urge that requisitions for maps and blanks be made several weeks in advance.

PART I

Summary of Fireball Observations

Date	Observer and Station	Beginning	Ending	Radiant
August 15, 1929, 8:28 P.M. E.S.T.				
	I. H. Friend, Torrington, Conn.	(a)		
	$\lambda = 73° 08'$			
	$\phi = 41° 48'$			
	A. J. Couble, East River, New York	(a)	$h = 54.9$ km	
	$\lambda = 73° 58'$			
	$\phi = 40° 48'$			
	C. W. Hudson, West Thornton, N. H.	(a)	$h = 69.2$	
	$\lambda = 71° 42'$			
	$\phi = 43° 54'$	mean	62.0 ± 7.2	
	Magnitude: Compared with Venus.		$\lambda = 76° 06'$	
			$\phi = 43° 33'$	(a)
Nov. 10, 1929, 6:00 G.C.T.				
	P. Polatt, S.S. Amelia	$h = 55.3$ km	$h = 30.0$ km	
	$\lambda = 74° 17'$ W			
	$\phi = 19° 58'$ N			
	O. H. Friz, S.S. S. C. T. Dodd	$h = 81.2^1$	$h = 40.0^1$	
	$\lambda = 75° 11'$ W			
	$\phi = 17° 34'$ N			
	weighted mean	72.6	wt. mean 36.7	
	Magnitude: "Shed brilliant light over entire heavens"	$\lambda = 72° 33'$	$\lambda = 72° 33'$	$\alpha = 66° 30'$
	Color: Greenish-white	$\phi = 18° 00'$	$\phi = 18° 00'$	$\delta = 18° 00'$
Aug. 20-21, 1930, 14:52 P.S.T.				
	R. E. Cook, S.S. Oregon	(a)	$h = 45.0$ km	
	$\lambda = 121° 50'$ W			
	$\phi = 36° 00'$ N			
	A. Neilson, S.S. El Segundo	(a)	$h = 64.0$	
	$\lambda = 123° 43'$ W			
	$\phi = 38° 43'$ N			

**Flower Observatory Reprint, No. 29.*

Date	Observer and Station	Beginning	Ending	Radiant
	G. W. Ridley, Alameda, Calif.		h = 43.0[1]	
	λ = 122° 12′ W	weighted mean	= 48.8 km	
	φ = 37° 48′ N			
	Magnitude: Between Venus and Moon		λ = 119° 09′ W φ = 38° 01′ N	(a)
	Color: Red; Yellow			
July 31, 1931, 10:30 P.M. C.S.T.				
	L. J. Wilson, Franklin, Kentucky	h = 62.5 km	(c)	
	λ = 86° 36′			
	φ = 36° 42′			
	C. P. Schafer, Nashville, Tennessee	h = 63.3	(c)	
	λ = 86° 47′			
	φ = 36° 10′	mn. 62.9		
		λ = 87° 12′	λ = 86° 52′ (c)	
	Magnitude: Between Venus and Moon.	φ = 36° 17′	φ = 36° 40′ (c)	
				α = 178°
	Color: Blue; White; Green.			δ = 3°
Sept. 16, 1931, 9:45 P.M. C.S.T.				
	R. E. Pennell, Waverly Hills, Ky.	h = 189.6 km	(b)	
	λ = 87° 45′			
	φ = 37° 43′			
	Mrs. W. M. Rinehart, Centerville, Tennessee	h = 148.9	(b)	
	λ = 87° 30′			
	φ = 35° 46′	mn. 169.3		
	Magnitude: ? (probably compared with Venus).	λ = 85° 21′		
		φ = 37° 12′	(b)	

NOTES

[1] Weight 2.

(a) Paths not definitely located except at end-point. Hence, beginning-point and radiant cannot be determined.

(b) Paths not definitely located except at beginning-point. Hence, end-point and radiant cannot be determined.

(c) Fireball passed below horizon as seen by each observer. The radiant was determined by projecting the paths on a globe. Reckoning backward from this and the beginning point, the point where the fireball would have struck the earth was determined. This point is in good agreement with the azimuths in which the fireball was seen to reach the apparent horizon. The fireball undoubtedly came within a very short distance of the earth; perhaps it actually reached the earth.

PART II

MISSOURI-ILLINOIS FIREBALL OF 1934 AUGUST 11

On the above date a splendid fireball, estimated at —7 magn., and coming from the Perseid radiant, was observed by J. Wesley Simpson and many others. He computed its atmospheric path and published a long account in the "Astronomical Discourse" of January-February, 1937. As this is a local amateur publication, it seems proper to reproduce the more important facts here, understanding that all the work was done by Simpson, and only a little checking by me.

Date	1934 August 11
Hour	8:25.5 C.S.T.
Began over	λ = 89° 45′; φ = +39° 49′ at 76 km
Ended over	λ = 90° 07′; φ = +39° 05′ at 43 km
Projected length of path	87 km
Real length of path	93 km
Observed geocentric velocity	40 km/sec
Radiant (unc. for Δz)	h = 21°; a = 202½°
Sidereal time at end point	266°

The fireball is described as whitish-yellow in color with two after-bursts of light, one being almost at the end of its path. It left a bright train, the duration of which was estimated by 20 people at from 2 to 15 minutes. One timed it by watch as 12 minutes. Unfortunately, only Simpson made drawings, which he reports as showing that the train drifted eastward. The heights depend upon observations made at Webster Groves, Missouri, and at Prairie du Rocher and Sparta, Illinois. Solutions were made combining the first with second and third, respectively, and the mean taken as the result. Excellent agreement was shown, though the heights derived are lower than for the average Perseid. It should be understood, however, that this was a larger mass than the average.

PART III

Oregon Fireball of 1932 September 22

A number of fine fireballs appeared over Oregon in 1931 and 1932, and the American Meteor Society Regional Director, Professor J. Hugh Pruett of the University of Oregon, had great success in collecting observations of these bodies. On several of them he has published articles. Fourteen reports were sent about a detonating fireball which appeared 1932 September 22, at 5:25 A.M., P.S.T. They were accompanied by a map and numerous notes on the data, made by him.

The observers and their stations were as follows:

Station No.	Observer and Location	Angle of Fall	Notes
1.	R. G. Hubbard, Portland		No sound.
2.	T. F. Tubb, Portland		No sound; pear shaped.
3.	J. Varco, near Sisters		Terrific sound, 3 or 4 more after.
4.	D. T. Carmody, 12 mi. west of Maupus		Explosion seen. No sound.
5.	A. G. Lindh, Moss Mt.	51°	No sound.
6.	J. Kirkland, Summer Lake	90°	No sound.
7.	H. H. Hayes, Lowell Mt.		Sound.
8.	E. E. Varco, near Sisters		Wakened; sounds lasted 30 sec. Exploded.
9.	E. Engles, Packsaddle Mt.		Long roll like thunder; wakened by it.
10.	H. Ingram, Lebanon	50°±	Only trail seen; lasted little after sunrise.
11.	P. Evenden, Gewars	90°	No sound.
12.	L. K. Scudder, Corvallis		Same meteor?
13.	P. Glaze, Scott Lake		Ground shaken; awakened by terrific roar.
14.	— Wright, Trail Camp		Ground shaken.

The following results have been derived here:

Began over	$\lambda = 121° 56'$; $\phi = +44° 25'$
Burst over	$\lambda = 121° 30'$; $\phi = +44° 16'$
Beginning height	80.8 km
End height (at bursting point)	6.3 km
Length of path	83.0 km
Observed geocentric velocity	28 km/sec
Local sidereal time at end point	81°.2
Radiant	$h = 64°$;* $a = 117°$; $\delta = 50°$; $\alpha = 42°$

*Zenith correction not applied.

There were six estimates for the beginning point, one obviously impossibly high. As most of the observers were in mountainous country, nearly all saw the

meteor go "to horizon," but they said that mountains cut off the view. Whether, therefore, the meteor fell as a meteorite, our data do not absolutely determine. The "bursting point" given above is taken from a drawing by observer 10, who indicates the lower end of the smoke train, which is assumed as point of burst. Observer 3 definitely saw the meteor pass north of him and disappear to south of east. His observation makes it certain that the meteor did not end west of the point chosen. His account proves fully that he was very near the ending point. It is my opinion that, as the object came so low, fragments certainly reached the ground and may be found a mile or more to the east of point of bursting.

It is needless to give all the data and the reasons for weighting them. Computations for fireballs are often so largely matters of judgment that different weighting would give widely different results. Observer 5 sent in far the most nearly complete and apparently accurate report. His results and the statements from 6 and 11 that the path was practically vertical were the strongest influences on the methods of handling the data. The heights of the upper and lower ends of the path, as given, are probably correct to 10 km and 2 km, respectively, and the radiant point to 6°. The duration of flight was estimated at from 1 to 8 seconds; the mean of six estimates was 2.96 seconds. The velocity derived from this is therefore liable to too great an error to be of much value.

The average estimate of size was one half the Moon, with little variation in estimates. Most observers gave blue-green as the original color, and red as the color at end. A. G. Lindh, station 5, described the trail as follows:

"The trail at first appeared to be a straight white line at an angle of 51° with the horizon. The trail was brighter in the apparent core of the cylinder. The outer edges were slightly diffused. After approximately two minutes a wavy zigzag effect became noticeable. It then appeared something like a sine curve.

"The change in appearance continued with the general alignment of the trail remaining straight and of the same length as at first. It appeared that, as the intensity of the light in the trail decreased, the wavy appearance increased. It was as though dust particles forming a solid bar had diffused and increased the area of the whole by forming a wavy trail which, if stretched out, would have been much longer than the original.

"As the trail became wavy in appearance the trail increased in breadth with a consequent decrease in the intensity of light.

"Both the widening and zigzagging changes continued constantly until the trail, as a whole, became invisible. This was after approximately eight minutes. During the next seven minutes faint traces could be seen of the diffused, wavy trail. After that the light was no longer visible."

He adds that it was visible along the *whole* path of the meteor. The train was therefore visible for 15 minutes, and its small changes seem to show there was almost no wind action upon it.

From the fact that people under or nearly under the path were awakened by roaring noises, and that some of them felt the ground shaken under them, it is obvious that the sound phenomena were particularly violent.

To everyone who contributed observations we extend our hearty thanks. The full credit for their collection and for a preliminary study of the data belongs to Professor J. Hugh Pruett, and is hereby gratefully given.

Flower Observatory of the University of Pennsylvania,
Upper Darby, Pennsylvania, 1938 March 26.

The Resistance of the Air to Meteors

(Third Paper)

By C. C. WYLIE

The notation of the earlier papers* will be used. The mass of the meteor will be denoted by M, the density by B, the radius by r, the velocity by V, the height by h, the resistance of the air by R, the altitude of the radiant or slope of the path by α, the density of the air at sea level by σ, the acceleration of gravity by g, the average velocity imparted to the air particles pushed aside by the meteor by GV, the momentum of the air pushed aside by the meteor by m, and the density of the air at the height h by σe^{-bh}.

For simplicity a spherical meteor will be assumed; curvature of path, variation in gravitational attraction, loss of mass, and irregularities in air density will be neglected. Then

$$(1) \qquad M(dV/dt) = Mg \sin \alpha - R$$

The term $M(dV/dt)$ represents the loss of momentum by the meteor, and R represents the rate of transfer of momentum to the air. The momentum of the air pushed aside can be obtained as in the first paper. Then by differentiation

$$(2) \qquad dm/dt = (G\pi r^2 \sigma \csc^2 \alpha/b)[be^{-bh}(dh/dt)^2 - (e^{-bh} - e^{-bh^0})d^2h/dt^2]$$

Since $R = dm/dt$, $M = (4/3)\pi Br^3$, and $V = -(dh/dt)\csc\alpha$ we have from (1) and (2)

$$d^2h/dt^2 = -(3G\sigma \csc \alpha/4bBr)[(e^{-bh} - e^{-bh^0})d^2h/dt^2 - be^{-bh}(dh/dt)^2] - g \sin^2\alpha$$

Let $A = 3G\sigma \csc \alpha/4bBr$. Then

$$(3) \qquad (d^2h/dt^2)[1 + A(e^{-bh} - e^{-bh^0})] - Abe^{-bh}(dh/dt)^2 = -g \sin^2\alpha$$

Let $y = (dh/dt)^2$. Then equation (3) reduces to

$$(4) \quad (dy/dh) - 2Abe^{-bh}y/[1 + A(e^{-bh} - e^{-bh^0})] = -2g \sin^2\alpha/[1 + A(e^{-bh} - e^{-bh^0})]$$

This is a linear differential equation of the form, where P and Q are functions of h,

$$dy/dh + Py = Q,$$

the solution of which is

$$ye^{\int P\,dh} = \int e^{\int P\,dh} Q\,dh + C$$

whence

$$y[1 + A(e^{-bh} - e^{-bh^0})]^2 = -2gh \sin^2\alpha[1 - A(e^{-bh^0} + e^{-bh}/bh)] + C.$$

Since $y = (dh/dt)^2 = V^2 \sin^2\alpha$

$$(6) \quad V^2 \sin^2\alpha[1 + A(e^{-bh} - e^{-bh^0})]^2 = -2gh \sin^2\alpha[1 - A(e^{-bh^0} + e^{-bh}/bh)] + C.$$

Evaluating C from the fact that $V = V_0$ when $h = h_0$

$$C = V_0^2 \sin^2\alpha + 2gh_0 \sin^2\alpha[1 - Ae^{-bh^0}(1 + 1/bh_0)]$$

Substituting this value of C in (6) and rearranging

$$(7) \qquad V^2 = \frac{V_0^2 - 2gh[1 - A(e^{-bh^0} + e^{-bh}/bh)] + 2gh_0[1 - Ae^{-bh^0}(1 + 1/bh_0)]}{[1 + A(e^{-bh} - e^{-bh^0})]^2}$$

For three figure work, the terms in 2g, representing the correction for gravitational attraction, can be dropped. With velocities above 10 kilometers, or 6 miles,

*POPULAR ASTRONOMY, **44**, 281, 1936; **46**, 104, 1938; *Contributions of the University of Iowa Observatory*, Number 7, 231. In the symbol e^{-bh^0} throughout this paper, "h^0" is to be read "h subzero."

per second, the correction is about one unit in the fourth significant figure. With these terms dropped, equation (7) reduces to the very simple form

$$V = V_0/[1 + A(e^{-bh} - e^{-bh_0})]. \tag{8}$$

If the velocity of a meteor is known to be V_0 at a height h_0, equation (8) gives the velocity V at any lower height h. If the velocity V at a height h is known, and it is desired to obtain a velocity V_0 at a greater height h_0, the equation can be put in the form

$$V_0 = V[1 + A(e^{-bh} - e^{-bh_0})] \tag{9}$$

For much work h_0 can be taken so great that the density of the air is negligible, and the term e^{-bh_0} can be dropped without appreciable error. Equations (8) and (9) then reduce to the forms

$$V = V_0/(1 + Ae^{-bh}), \text{ and } V_0 = V(1 + Ae^{-bh})$$

Occasionally, one desires to calculate the velocity with which a large meteor should strike the earth, when V_0 is known for an h_0 so great that the atmosphere is negligible. For this problem equations (8) and (9) reduce to

$$V = V_0/(1 + A) \text{ and } V_0 = V(1 + A)$$

University of Iowa, April 13, 1938.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
Department of Astronomy, University of California at Los Angeles

President of the Society: H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver

Secretary of the Society: ROBERT W. WEBB, Department of Geology, University of California at Los Angeles

The Atmosphere of the Moon and Lunar Meteoritic Erosion

By LINCOLN LA PAZ,
Department of Mathematics, The Ohio State University, Columbus

Introduction.—The singularly sharp and unworn aspect of the visible hemisphere of the moon is a matter of common knowledge. So remarkably free from the forms characteristic of vigorous and long-continued erosion is the lunar surface, that selenography would seem to furnish scant basis for statements such as the following:[1]

> ". . . the earth's atmosphere protects us from the direct striking action of these bodies [meteorites], . . . On the moon there is no protection, and there is a continual rain of tiny projectiles moving with velocities up to at least 44 miles per second, . . . These strike the surface at every conceivable angle. Therefore there must be a continual effect, not unlike erosion, going on, because not only would these projectiles break off sharp edges, when striking at an angle, but themselves would be fused and carry off a tiny amount of fused material from the rock struck, if they went through it."

Although, as just remarked, the nature of the lunar topography appears to offer no support for the assertion quoted (an assertion resting obviously on the assumption, *A: that since the surface density of an admissible lunar atmosphere*

is, necessarily, very small, it follows that the efficacy of such an atmosphere as a shield against meteoritic bombardment is negligible), nevertheless, now, as in the past, this view has its advocates. *E.g.* in an interesting recent paper, L. J. Spencer,[2] in contrasting the relative effectiveness of meteoritic bombardment of the earth and the moon, states

> "On the moon, with the absence of an atmosphere, conditions are very different. Meteorites there will encounter no check on their velocity. They will not be reduced in size and stony masses will not be broken up. They will strike the surface at 20 or 40 or more miles per second."

Spencer, himself, notes that if such a bombardment is now reaching the surface of the moon, it is strange that no visible craters are produced. An objection of a similar nature was raised a number of years ago by Gordon,[3] who was puzzled that no observations of luminous phenomena consequent upon the 20,000 or more high-velocity impacts which he estimated would occur daily on the unilluminated portion of the lunar surface had been reported by either visual or telescopic observers. It is the purpose of the present paper to set forth certain observational and theoretical results which have a direct bearing on the conclusions reached and the questions raised by the writers referred to previously.

§1. *Observational Evidence concerning the Visibility of Meteoritic Impact-Flares on the Moon.*—Observations made at the moment of fall of the Podkamennaya Tunguska, Siberia, meteorite of 1908 June 30, show that such luminous phenomena as Gordon anticipated would certainly be visible from the earth if meteorites struck with undiminished cosmic velocity directly against the surface of the moon. The Siberian meteorite, although it hit the earth with an *impact-velocity*, v, much less than its extra-atmospheric velocity,[4] produced an *impact-flare* visible in full daylight as a "fiery pillar" towering above the horizon[5] at Ilimsk, Nizhne-Ilimsk, Kirensk, Nizhne-Korelinskaya, and other Siberian towns.[6] Even at stations 500 km. distant from the point of fall, this impact-flare was brighter than stellar magnitude —21.[7] Hence, if the Siberian meteorite had fallen with the same velocity v on a favorably placed, unilluminated region of an airless moon, the resultant luminosity would have been brighter certainly than magnitude —6.5 as seen from the earth, and would have been, therefore, a spectacular object much brighter than Venus at her maximum, even to the visual observer.

Astapowitsch has found by several different methods that the kinetic energy of the Siberian meteorite at the instant of impact was about 10^{23} ergs. He estimates the impact-velocity to have been about 35 km. per second. These estimates lead to an impact-mass of approximately 18 tons, in fair agreement with Whipple's value of 12 tons. Since the kinetic energy of a moving meteorite varies jointly as the mass and the square of the velocity, and since the fraction of the kinetic energy of a meteorite transformed on impact with the surface of an airless moon into energy of visible radiation must be practically independent of the size of the meteorite, it can be shown that a flare of magnitude —6.5 would have been produced by a 4½-ton lump of the Siberian meteorite striking the moon with the maximum velocity suggested by Olivier. Similarly for $v = 50$ km. per second (a velocity somewhat less than the average velocity mentioned by Spencer), it is found that fragments of the Siberian meteorite of weights 176 pounds, 22 pounds, and 1.76 pounds, would have produced impact-flares of stellar magnitudes —1.5, +0.75, and +3.5, respectively. These results show that very small meteorites falling with cosmic velocity onto the dark portions of an airless moon would produce luminous phenomena discernible without telescopic aid.[8]

§2. *Theoretical Considerations Relative to the Visibility of Impact-Flares.*—The question of the visibility of meteoritic impact-flares on an airless moon can be approached in another manner. It is easy to compute the number of calories generated when a meteorite of known mass and velocity strikes the surface of the moon. Under reasonable assumptions as to the amount and specific heat of the masses involved, it is then possible to compute the temperature of the impact-flare. From known results on the luminous flux of a black body as a function of its absolute temperature and the value of the least mechanical equivalent of light,[9] it is then possible approximately to determine the brightness, b, in candles per cm.^{2} of the flare. The value of b so obtained is too large, not only because only part of the kinetic energy of the meteorite is transformed into energy of visible radiation but also because the incandescent mass under consideration is a non-black body. After suitable corrections are applied, it is found that the brightness b of the flare is very approximately the same as the intrinsic brilliancy of the solar surface. An estimate of the stellar magnitude of such a flare on the moon can accordingly be made, once we know the area it presents to the terrestrial observer. If we suppose that for $v = 50$ km. per second the flare produced by a 10-kg. mass presents to the terrestrial observer an area equivalent to that of a circle of radius 5 meters lying in a plane perpendicular to the line of sight,[10] then it is found that the stellar magnitude of such a flare as seen from the earth would be approximately $+0.6$.[11] This result, which is very near that obtained by the method of the previous section for the magnitude of the flare produced by a 10-kg. (22-pound) mass with $v = 50$ km. per second, confirms our earlier conclusions that meteorites weighing more than, say, 10 pounds, which hit the surface of an airless moon, will produce luminous phenomena visible on the earth.

According to results published by C. C. Wylie,[12] at least 6000 meteorites weighing 10 pounds or more plunge into the earth's atmosphere annually. Since the surface area of the moon is about 1/14 of that of the earth and since on the average one-fourth of the moon's surface is visible to a terrestrial observer but unilluminated by the sun, the number of such meteorites producing on an airless moon impact-flares favorably placed for observation would be about 100 per year! As it seems incredible that no one of the more than half-million visible flares which, on the hypothesis of an airless moon, would have occurred in the course of historic times should have been observed,[13] we are, on the one hand, forced to the conclusion that the basic assumption, A, stated in the introduction, is false, and, on the other, led to inquire just how the rare lunar atmosphere can function as an effective shield against meteoritic impacts.

The conclusion that assumption A is false was reached many years ago by W. H. Pickering,[14] and, it would appear, independently, by A. C. D. Crommelin,[15] prior to 1921. Pickering, employing the well-known approximation that the atmospheric pressure above the earth is reduced by one-half for each successive ascent of 3.5 miles and the analogous result for the moon, on which the force of gravity is one-sixth of that on the earth, found that if the surface density of the atmosphere on the moon was only 1/6000 of that at the surface of the earth, still the two atmospheres would be of equal density at a height of about 53 miles. He inferred that the lunar atmosphere, in spite of its rarity, ". . . is quite sufficient to render luminous and destroy all the smaller meteors [meteorites] before they can strike the surface," and suggested that, since at heights above 53 miles, the lunar atmosphere is *denser* than the terrestrial, "shooting-stars" on the moon first become luminous at an altitude of about 210 miles.

Crommelin, apparently using the pressure-height relation deducible for an iso-

thermal atmosphere, concluded that even if we were to suppose that

> ". . . the density at the moon's surface is only 10^{-4} of that on earth (a quantity that it may quite well exceed), then at a height of some 43 miles the densities of the two atmospheres would be equal, while if we went still higher that of the moon would be the denser. Thus it turns out that the moon's atmosphere may form as efficient a screen against meteoric [meteoritic] impact as the earth's."[16]

In view of the fact that these important remarks seem to have escaped the attention they merit, and that neither a critical examination of the validity of the assumptions made by Pickering and Crommelin nor the details of the latter's calculations appear to have been published, it seems well worth while to indicate under precisely what hypotheses results of the sort previously described can be obtained. This is the object of the next section of the present paper, in which attention is restricted to the remarks of Crommelin, since he worked under the same assumptions as Pickering, but with less approximative formulas.

§3. *Lunar Atmospheric Density under the Simplest Hypotheses.*—In considerations relating to the density of the lunar atmosphere, effects due to the very slow axial rotation of the moon are negligible. In what follows effects attributable to the rotation of the earth also will be ignored. This procedure is permissible, since it will not be found necessary to perform calculations involving heights above the surface of the earth so large that the rotational term will become of any importance. Initially, we shall make also the following assumptions, the legitimacy of which will be considered in detail later: (1) the gravitational attractions of the earth and moon are constant throughout the height ranges under consideration; (2) the entire atmospheres of both bodies are in isothermal equilibrium.

We shall denote by g_e the gravitational attraction of the earth, by γ_e the ratio of the specific heat of air at constant pressure to the specific heat of air at constant volume, by T_e the constant temperature of the isothermal atmosphere on the earth, and by V_e the velocity of sound in air at temperature T_e. The same symbols, with the subscript e replaced by m, will be used to denote the corresponding quantities on the moon. Under hypotheses (1) and (2), the atmospheric densities, δ_e, δ_m, at a height of h km. above the surfaces of the earth and moon, respectively, are then given by the familiar formulas

$$(3.1) \qquad \delta_e = \Delta_e \times \exp(-g_e\gamma_e V_e^{-2}h); \quad \delta_m = \Delta_m \times \exp(-g_m\gamma_m V_m^{-2}h).$$

In (3.1) Δ_e and Δ_m are the values of δ_e and δ_m for $h = 0$. Let us assume that $\Delta_m = \lambda\Delta_e$ $(0<\lambda<1)$ and propose, with Crommelin, the problem of finding, if possible, a value of h such that $\delta_m = \delta_e$. On taking $g_e = 6 \times g_m = 9.81$ meters per sec.^{2} and writing μ for the natural logarithm of λ, it is easily verified that such a value of h always exists and is, in fact, determined by the relation

$$(3.2) \qquad h(1.64\,\gamma_m V_m^{-2} - 9.81\,\gamma_e V_e^{-2}) = \mu.$$

The constant temperature of the isothermal region above the earth is generally taken as $T_e = -53°$ C. At this temperature, γ_e has the value 1.407 and V_e the value 297 meters per sec.[17] With these numerical values (3.2) becomes

$$(3.3) \qquad h(1.63\,\gamma_m V_m^{-2} - 0.0001564) = \mu.$$

It is impossible to proceed further without a knowledge of the values of μ, γ_m, and V_m. If, following Crommelin, we assume (3) that $\lambda = 10^{-4}$, and suppose, furthermore, (4) that the constant temperature of the isothermal region on the moon is $T_m = T_e = -53°$ C., and (5) that the lunar and terrestrial atmospheres are of the same percentage composition, then $\mu = -9.21$, $\gamma_m = \gamma_e = 1.407$ and

$V_m = V_e = 297$ m. per sec. With these values (3.3) gives $h = 70.69$ km., which checks the result of Crommelin.

We have now to examine the legitimacy of the various assumptions previously enumerated. First, we shall consider (3). Examination of the literature discloses that estimates of λ range in value from 1/300 to 10^{-6}. In general, the largest values are suggested by the selenographers and others who have the closest observational acquaintance with the moon; the smallest by those who, in calculations of the rate of loss of the moon's atmosphere by use of relations derivable from the kinetic theory of gases, appear to disregard the fact that the proper temperature to employ in these formulas is the temperature T of the *outer* region of the lunar atmosphere. Since the formulas in question involve a factor of the form $\exp(cT^{-1})$, it is evident that they are very sensitive to changes in T. In particular, if T is taken equal to the maximum *surface* temperature (393° K.) observed on the full moon—a choice frequently made without any effort at justification—then a very rapid rate of loss of the lunar atmosphere will be found and the unwarranted inference that the moon can retain no atmosphere will be drawn. As far as actual observational evidence goes, it appears that values of $\lambda < 2 \times 10^{-4}$ have not as yet been excluded. Hence Crommelin's choice, $\lambda = 10^{-4}$, seems permissible. It may be noted that, for fixed γ_m and V_m, (3.3) shows that an increase in λ would lead to a smaller value for h.

We shall examine next assumption (5). It is, of course, highly improbable that the atmosphere of the moon has the same percentage composition as that of the earth. Since γ_m enters only linearly into (3.3), and since it is known that the ratio of the specific heats of the air changes but little with change in percentage composition, assumption (5) is permissible as far as γ_m is concerned; but it is otherwise with respect to V_m, the reciprocal of the square of which appears in (3.3), for the velocity of sound varies considerably from one gas to another.[13] This assumption must, therefore, be regarded as illegitimate. Similarly, the assumption (2) is only partially justified, since the thickness of the adiabatic atmosphere on the earth is not negligible, although that of the moon very probably is. It would be more accurate, therefore, to replace (2) by the assumption that in the first equation of (3.1), h is measured from the top of the adiabatic atmosphere and Δ_e is the density at this level. Since this condition would be equivalent to an increase in λ, it follows from an earlier remark that a *smaller* value would result for the height at which $\delta_m = \delta_e$.

Assumption (4), also, seems unjustified, since, under the isothermal hypothesis, it does not seem likely that T_m would exceed the minimum surface temperature (—153° C.) observed on the dark side of the moon. For an atmosphere with the probable composition of that on the moon, a decrease in T_m would decrease V_m and hence *increase* h. Finally, assumption (1) is certainly not fulfilled and the magnitude and sign of the error produced by its adoption cannot be determined by inspection, although one may surmise that this error is small.

It seems probable that the explanation of the efficacy of the rare lunar atmosphere as a shield against meteoritic bombardment as given by Pickering and Crommelin is the correct one; nevertheless, the critical examination just completed shows that a final decision must await a recalculation of h on the basis of assumptions conforming more closely to the actual state of the lunar atmosphere, as revealed by modern observations and theory, than those heretofore adopted.

The writer has found it easy to treat the case in which g_e and g_m are regarded as functions of h; and of the remaining assumptions only (2) is discarded. The resulting value for the height at which $\delta_m = \delta_e$, is approximately 12 km. *less* than

the value determined earlier in this section. On the other hand, difficulties, due chiefly to the absence or imperfection of necessary data, are encountered, *e.g.* when we seek to formulate a satisfactory substitute for assumption (4). These matters will be treated in detail in a later paper.

REFERENCES AND FOOTNOTES

[1] Olivier, C. P., *Meteors* (1925), 254.
[2] Spencer, L. J., *Nature*, **139** (1937), 655.
[3] Gordon, J. W., *Nature*, **107** (1921), 234.
[4] The Siberian meteorite reached the earth after an exceptionally long flight through the densest portion of the atmosphere, on account of the small inclination of its path to the plane of the horizon.
[5] The *vertical* pillar of the impact-flare was very distinct from the terminal portion of the *horizontal* luminous trail.
[6] Astapowitsch, J. S., *Astr. Jour. Soviet Union*, **10**, 4 (1933), 480 *et sqq.*
[7] Astapowitsch, *loc. cit.*, [6], 481.
[8] *Cf.* in this connection the experimental work of R. H. Goddard (*Smithsonian Misc. Coll., Publ.* No. 2540 (1919), 56), who inferred from his observations of flashlight-powder charges fired in a vacuum that the explosion of as little as 2.67 pounds of flashlight powder on the lunar surface at the time of new moon could be rendered just visible by use of a telescope 12 inches in aperture.
[9] See, *e.g.* W. W. Coblentz and W. B. Emerson, *Scientific Papers of the Bureau of Standards*, No. 305, and H. E. Ives, *International Critical Tables*, **5** (1929), 436.
[10] This is a reasonable assumption in view of the huge observed dimensions of the flare produced by the 12-18-ton Siberian meteorite, for which v was only 35 km. per second.
[11] In August, 1925, the writer communicated to C. P. Olivier by letter the details of a similar calculation leading to a precisely equivalent result.
[12] Wylie, C. C., *P. A.*, **44** (1936), 91.
[13] It is just conceivable that the artist who set the fashion (often held up to scorn) of painting stars within the dark portion of the moon was making a commendable effort to depict the appearance of meteoritic impact-flares on the lunar surface! Servile copying of such a quirk, apparently without a basis in reality, is a not unfamiliar phenomenon in the artistic world—witness G. Romano's carnations!
[14] Pickering, W. H., *Astronomy and Astro-Physics*, **1** (1892), 778-82.
[15] Crommelin, A. C. D., *Nature*, **107** (1921), 235.
[16] *Splendour of the Heavens*, **1** (1923), 244.
[17] *Cf.*, in this connection, *International Critical Tables*, **5** (1929), 80; **6** (1929), 462.
[18] *Cf.*, in this connection, *International Critical Tables*, **6** (1929), 462-3.

Meteoritic Iron Phosphide

By JOHN DAVIS BUDDHUE,
99 South Raymond Avenue, Pasadena, California

ABSTRACT

The composition of schreibersite is very variable, but frequently polygons of iron, nickel-cobalt, and phosphorus percentages strongly suggest that the formula is Fe_2NiP. A secondary maximum in the nickel-cobalt polygon, together with a study of the individual analyses, indicates that, in general, the phosphide known as *rhabdite* has somewhat more than the required quantity of nickel, while the more massive, "true" schreibersite contains somewhat less. References are given to work showing that schreibersite is body-centered tetragonal. Schreibersite lamellae are known to occur parallel to (100), (210), (211), (110) (Brezina lamellae), and (111). The last-mentioned form is described for the first time in connection with Widmanstätten figures in the Canyon Diablo, Arizona, meteorite. It is also some-

what different from a similar occurrence in the Rodeo, Durango, Mexico, meteorite. The name *Shepard's lamellae* is proposed for the lamellae parallel to (111).

According to G. P. Merrill,[1] W. Haidinger discovered and named, in 1847, the meteoritic mineral which we call *schreibersite*. However, C. U. Shepard had previously found that the black, or brownish-black, mud produced when meteoritic iron is dissolved in acids, consists of iron, nickel, and phosphorus. Because of its insoluble nature, he named this *dyslytite*. He also described a black, semi-metallic mineral, which he found in the Bishopville, South Carolina, aërolite, as being probably a chromium sulphide (Cr_2S_3), and named it *schreibersite*. Subsequently, W. S. Clark[2] and others referred to the phosphide from the Magura, Arva, Czechoslovakia, meteorite as "schreibersite of Patera," and intimated that this was the same as Shepard's dyslytite. This name, shortened to *schreibersite*, has since come into general use, in spite of Shepard's protests. Later Shepard himself distinguished a phosphide from Patera's schreibersite, and named it *partschite*.[3] Another name applied to the phosphide was *lamprite*, but none of these has survived except *schreibersite*. Shepard's schreibersite was perhaps *daubréelite*,[4] although there are objections to this suggestion.

The composition of schreibersite is exceedingly variable, and it is not impossible that more than one phosphide exists in meteorites. I have constructed frequency polygons (see Fig. 1), showing the frequency of the several percentages of the three principal constituents, from 70 analyses collected from various sources. The ordinate is an arbitrary scale of frequency; the abscissa is graduated accord-

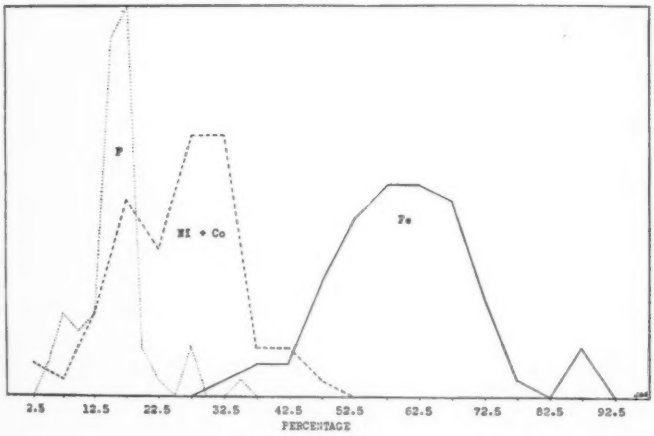


FIGURE 1
FREQUENCY POLYGONS FOR METEORITIC IRON PHOSPHIDE

ing to the class marks of the percentage interval (5%). Because of the small range, the interval for phosphorus was half as large as that for the metals.

The maxima of the three polygons correspond very well to the calculated composition for Fe_2NiP. The large spread of the iron and nickel-cobalt polygons means probably that there is a considerable amount of mutual replacement of these metals, and thus suggests that schreibersite may be a mixture of two isomorphous phos-

phides and that the average formula Fe_2NiP may be simply the result of the most common conditions of equilibrium. Not any of the secondary maxima correspond to known, or theoretically possible, phosphides, and these might disappear if more analyses were available.

An examination of the analyses themselves shows many cases corresponding to Fe_2NiP, but there are quite a few corresponding to formulae ranging from $(Fe, Ni)_3P$ to $(Fe, Ni)_{16}P$. I think that some of the phosphides with these peculiar compositions may be really solid solutions of some more or less definite phosphide and metal. Support for this idea is found in the very occasional report of flexible schreibersite, and the fact that the schreibersite of the Hoba West, Southwest Africa, meteorite, contained a core more soluble in acids than the outside.[6] Rhabdite was once thought to be a separate form of schreibersite occurring as fine needles, and distinct from the more massive variety. It is now believed that the only difference between the two is in habit.

The nickel-cobalt polygon shows a distinct secondary maximum which I believe has a real significance. When the individual analyses are examined, it is found that approximately 75% of the analyses of schreibersite contain somewhat less nickel than is required by the formula Fe_2NiP. Conversely, about the same percentage of the analyses of rhabdite shows more nickel than the formula requires. It follows, therefore, that the secondary maximum is due primarily to schreibersite, while the principal maximum is due to rhabdite. Each is doubtless more or less modified by the other, and rhabdite seems to predominate.

As for the crystallography of schreibersite: there have been indications from time to time that it is tetragonal, but it was not until measurable crystals were obtained from the Ruff's Mountain, South Carolina, iron, that the crystal system of the mineral was known. These crystals were measured by E. T. Wherry,[8] who found that they are really tetragonal. This conclusion was confirmed and extended by Heide, Herschkowitsch, and Preuss,[7] who examined schreibersite from the Cerros del Buen Huerto (Buey Muerto), Chile, meteorite with X-rays and found that is body-centered tetragonal, with $a = 9.013$ and $c = 4.424$ Å. The calculated specific gravity is 7.44.

One of the several modes of occurrence of schreibersite is as thin plates, often arranged regularly with respect to the crystallographic axes of the metal. In Cerros del Buen Huerto (H), the plates are arranged parallel to (100), (210), and (211). They are parallel to the cube (100) in Santa Rosa, Tunja, Boyaca, Colombia (Ob or H); Seeläsgen, Schwiebus, Brandenburg, Prussia (Ogg); Braunau, Trutnov, Bohemia (H); and Misteca, Oaxaca, Mexico (Om). In Indian Valley Township, Floyd County, Virginia (Hb), they are parallel to the Neumann lines. Brezina found them oriented parallel to the dodecahedron in Tazewell, Tennessee (Off); Ballinoo, Western Australia (Off); and Narraburra Creek, New South Wales (Off). These latter have been named *Brezina lamellae*.

In describing the Rodeo, Durango, Mexico, meteorite, Dr. O. C. Farrington described several large schreibersite lamellae with maximum dimensions of 4×0.5 cm.[5] These are always bordered by a band of swathing kamacite about 1.5 mm. wide, and, according to Farrington, are arranged parallel to the Widmanstätten figures. However, a close examination of Plate III of the same publication suggests that some slight deviation from strict parallelism is often present.

In their description of the shale-ball iron of Canyon Diablo, Arizona, Merrill and Tassin noted the absence of Widmanstätten figures, and the presence of an abundance of schreibersite lamellae "oriented in the directions of the sides of

triangles which correspond to three directions of the octahedron.'"[9] I take this statement to mean that the lamellae were parallel to the octahedron.

I have recently had an opportunity to examine a small specimen of Canyon Diablo iron (Fig. 2). It is a flat, elliptical mass, measuring roughly 6 × 4.5 × 1.5 cm. This has been divided into two pieces about 7 mm. thick. I have not seen one part, but the other shows a number of schreibersite lamellae, a little over 1 mm.

FIGURE 2
AN UNETCHED SURFACE OF A CANYON DIABLO METEORITE WITH OCTAHEDRALLY ARRANGED SCHREIBERSITE LAMELLAE: ¾ NATURAL SIZE

wide and from 1 to 8 mm. long. These lie in the centers of kamacite bands averaging 1.77 mm. in width. The kamacite has normal taenite borders, but there is no border around the schreibersite; this does, however, contain particles of kamacite. None of the peculiar features observed by Merrill and Tassin was observed. There is also an irregular oval nodule of schreibersite, measuring about 6 × 14 mm., containing a little graphite or black oxide.

The shale-ball iron differs from this particular specimen in possessing no Widmanstätten figures, and containing large amounts of lawrencite. The latter is almost absent from the specimen in question, although the microscope shows many minute rust spots on the schreibersite. I think that this specimen of Canyon Diablo is perhaps intermediate between the normal and the shale-ball types of structure.

I am indebted to Dr. J. L. Smith (not the meteoriticist) for the opportunity to examine this specimen. I suggest that octahedrally arranged schreibersite lamellae might be designated as *Shepard's lamellae*, since, although he had priority,[10] neither of his names for meteoritic iron phosphide has been retained.

REFERENCES

[1] *U. S. Nat. Mus. Bull.*, 149, p. 12 (1930).
[2] *Am. Jour. Sci.* (2), **15**, 8 (1853).
[3] *Am. Jour. Sci.* (2), **15**, 366 (1853).
[4] *Am. Jour. Sci.* (2), **2**, 377-392 (1846).
[5] L. J. Spencer, *Min. Mag.*, **23**, 1 (1932).
[6] *Am. Min.*, **2**, 80 (1917); **3**, 84 (1918).
[7] *Chemie der Erde*, **7**, 483 (1932).
[8] *Field. Mus. Pub.* 101, p. 2 (1905).
[9] *Smithsonian Misc. Coll.*, **50**, Pt. 2, 209; Pt. 4, 484 (1908).
[10] *Am. Jour. Sci.* (2) **2**, 377-392 (1846).

Notice of the Postponement of the Sixth Annual Meeting

The President and the Secretary wish to state that, on account of a number of unexpected developments, it seems inadvisable to hold the Sixth Annual Meet-

ing of the Society in Ottawa, Ontario, Canada, in June, 1938, as previously announced (*C.S.R.M., P.A.*, **46**, 111, February, 1938). Accordingly, notice is hereby given that this meeting will be postponed until such time as may be announced later in these CONTRIBUTIONS.

Early Determination of the Height of a Meteor

The following note from the source indicated was forwarded to us with the thought that those who at present are investigating the phenomena attending the flight of meteors might wish to compare their impressions with those made upon workers along the same line a century and a half ago. It also serves to impress upon the reader the repetition of the cosmic processes. The phenomenon itself, although described in terms different from those used today, has certainly been witnessed many times since the date of the record, and doubtless will recur again and again in the future. ED.

Connecticut Journal, November 19, 1788, No. 1099.

October 17th, 1788, riding on the road, in a S.W. course, a little after six o'clock P.M. I was suddenly surprised with a glaring light, which caused me to look up; when, lo! a globe, luminous, and in appearance like fire in the zenith, which affrighted my horse, nevertheless, I kept my eyes on the rare Phenomenon, which gave me an opportunity, to make the following observations, with respect to magnitude, course, velocity and disappearance. The magnitude appeared to me to be equal to the moon at full. This Meteor was exceeding bright, and from its nucleus, proceeded a long, luminous conic tail, whose base was the diameter of the nucleus near the base; this tail was as bright as the nucleus itself; but grew paler, the farther it receded from it. The course of this Meteor was nearly from N.E. by E. to S.W. by W. and it appeared to move, on an angle a little inclined to the plane of the horizon, describing the conjugate figment of an ellipse. The greatest apparent altitude, did not exceed half a mile; but the real altitude must have been some miles.

The velocity was very great indeed, if we consider, that it passed over about 90 degrees, in 6 seconds of time. About three minutes after it had disappeared, I heard a report, like thunder, or large cannon at a distance. Now, whether this report proceeded from a collection of phlogestic exhalations collected round this Meteor, in passing through the upper regions of our atmosphere, and set on fire, by the great rapidity of motion, and the consequent friction thence arising, in the nature of thunder and lightning, is a question: be that as it may, the distance of explosion, (if the time allowed above be true) may be ascertained, by the known laws of the velocity of sound, which is about a mile in five seconds of time. Now if we allow three minutes to have elapsed, from the disappearance of the Meteor, till the report was heard, the said distance of explosion, will be about 40 English statute miles. And that this was nearly the true distance, is confirmed by information from Poughkeepsie, in the State of New York, where the sound was heard to the Eastward. Now Poughkeepsie, lies about 60 miles, in a direct western course from Milford. The annexed diagram, will give the best idea, as to the distance of explosion and perpendicular altitude.

Now, if we make a reasonable allowance, for the curvature of the earth's surface, we shall have about 25 or 26 miles for the altitude of this Meteor, above the surface of the earth. And by enquiry, I find, the further the report was heard to the eastward of Milford, it was by some seconds longer, arriving at the greatest audible distance, than it was at Poughkeepsie; whence I judge, the place of ex-

plosion, was about midway between Poughkeepsie and Milford, and about 25 miles above the surface of the earth.

The manner of disappearance, to me, and others, was very similar, viz. when it had reached within about 20 degrees of the horizon, it seemed to fall to pieces, in different directions, like a large body of hot cinders, accompanied with numerous sparkles of fire. At this time, it was not cloudy, but a thin haze was observable in the East, otherwise, a fine star light evening. The preceding day, had been uncommonly hot for the season; and the wind strong at S.W. in the afternoon, and so continued until after the explosion, when it soon became calm.

These are the most remarkable circumstances, attendant on this rare appearance; and as my mind, at this time, was tranquil, I was not so liable to deception, as if it had been much agitated.

However, whether the appearance of this Meteor be natural, or portentous, a contemplative mind will naturally suggest to itself some important lesson, and consider, that if the minuter works of the Deity, as Thunder, Earthquakes and Meteors, in our earth and atmosphere, to us appear so terrible, what will that last important, closing act of the great Drama be, when the Judge of quick and dead, shall descend from on high, in flaming fire? Amazing! beyond description amazing! What manner of persons ought we then to be? — Seeing that ye look for such things, be diligent, that ye may be found of him in peace, without spot, and blameless.‖

I am yours,

NARRATOR.

‖2 Pet. iii. 14.
Milford, October 31, 1788.

On the Double Heating of a Meteorite

In the mineralogical analysis of the Moore County, North Carolina, meteorite, E. P. Henderson and Harry T. Davis[1] have concluded from the structure of the meteorite, that on two separate occasions it had been heated to high temperatures. No explanation was given of how this may have occurred. It was pointed out, however, that a close approach to the sun was probably not the explanation, as the stone would fall into the sun if it got close enough to be heated to such a high temperature.

The following is suggested as an explanation of the double heating.

T. C. Chamberlin set forth a theory of the formation of comets. He concluded that comets may have developed from matter ejected from the sun. This matter leaves the sun in vaporous form and as it gets farther and farther away from the sun, condenses into chondrules. The matter continues to an aphelion point somewhere beyond the orbit of Neptune or Pluto after about two million years, and remains in that neighborhood for another million years during which time chondrules are drawn together by their mutual attraction into a compact swarm. Thus a comet is born.

Assume that the meteorite under discussion was originally a part of the sun and was left floating alone when the solar system was formed. After it had been "out in the cold" for a few million years, it was included in the birth of a new comet, getting its second heating as a member of the comet's head. The comet lived its span of years, then disintegrated, and the stone was again a solitary wan-

[1] "Moore County, North Carolina, Meteorite—A New Eucrite," *The American Mineralogist*, April, 1936, page 215.

derer until it was gathered to earth as its resting place for the next few million years.

DAVIS P. RICHARDSON.

University of Arkansas.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Four Peculiar Variables in Carina: Harvard Bulletin 908, just off the press, contains an investigation by Mrs. N. K. Greenstein of four variables which appear to be involved in the dark nebulosity of Carina. The nebulosity is thought to affect their variability aside from their intrinsic variation.

AG Carinae, 1052*59*a, with a spectrum similar to P Cygni was first suspected of variability by Wood and later by Innes. Mrs. Greenstein has studied the light variations covering the years 1895 to 1936, and describes them as slow and irregular, between magnitudes 7.1 and 9.0, with certain maxima during the interval being similar in character. A further perusal of the plotted light curve shows that, although the variations are slow and irregular, there is a suggested period, or cycle, of about 2000 days. A comparison of the light curve from J.D. 2412000 to 2418000 and 2422000 to 2428200 shows many indications of similarity in curve, wave for wave running strikingly parallel.

GG Carinae: Observations covering the years 1902 to 1936 reveal much of unusual interest in the behavior of the variable star GG Carinae. Miss Hoffleit listed it among galactic stars with P Cygni type spectra, as variable, of the eclipsing type, range 9.5 to 10.0, and confirmed Kruytbosch's half period of 31 days. She stated that GG Carinae is the only one of the 19 P Cygni stars she studied that gives any indication of periodicity. Mrs. Mayall's star, — Pavonis, 181066, (see these notes, February, 1937), is the only other star with a P Cygni spectrum that shows periodicity, and that star is unique among eclipsing systems.

An examination of the nearly 600 photographic observations made by Mrs. Greenstein leaves much still to be desired before we can definitely decide that the variable is of the eclipsing type. Although there is a persistency of the double period of 62 days, the variations are not regular over the years studied. There are exceptions to continuously periodic variation in the way of intervals of constant brightness. The mean light curve has many features not usually found in eclipsing stars and many more observational data are required for final analysis of the star's variability.

T Carinae: The star T Carinae, 1051*59*, was considered so well proved as variable as to have been assigned a letter. The spectral type is K0, and Paddock, from a consideration of his radial velocity measures, which showed a constant velocity, concluded that the star was probably not variable. This view might well have been assumed if his radial velocity measures were made during the early years of the present century when the star showed little evidence of variability.

A plot of Mrs. Greenstein's observations, 1895 to 1936, shows that the star was irregularly variable with marked fluctuations prior to 1898 and after 1930. In the intervening years it became progressively brighter, 7.8 to 7.1, with only slight fluctuations in light. Mrs. Greenstein concludes that T Carinae is definitely vari-

able, with variations which may perhaps not be intrinsic but in some way connected with the dark nebulosity found in the Carinna region.

ES Carinae: ES Carinae, 110659, was extensively studied by Dr. Hertzsprung as well as by Mrs. Greenstein. The range in variation is not large, $13^{M}.0$ to $14^{M}.5$, photographic, and there are some very sudden fluctuations in light followed by intervals of a hundred days or more when there is little, if any, change in magnitude. It certainly has no resemblance to an eclipsing variable. Possibly it is more nearly related to the type of variation found in decadent novae or in stars of the T Orionis type. T Orionis, like ES Carinae, is also involved in nebulosity.

Although the observations are decidedly scarce and even lacking for long periods of time, there is some indication of sudden activity on the part of the star at intervals of ten years. Other fluctuations, of course, are noted between the intervals but not with the regularity of the period just mentioned.

Harvard Conference on Cepheid Variables: One of the main problems being studied at Harvard Observatory is Cepheid variability. Not only observationally but theoretically the problem is being handled by numerous members of the staff. On Friday, April 15, an all-day conference on the subject was held at Harvard, under the direction of Dr. Shapley, at which representatives from many eastern colleges and observatories were present, as well as Miss Joyner from Mount Wilson.

Mrs. C. Payne-Gaposchkin opened the conference with a general résumé of the present knowledge of Cepheids, including their properties and relations, and the problems still unsolved. Subsequent papers dealt with Cepheid atmospheres, the period-luminosity relation, secondary periods, light curves and the spectra of special stars, discovery and classification, and stability problems. The program of papers was as follows:

Dr. Cecilia Payne-Gaposchkin: A Survey of the Cepheid Problem.
Dr. Donald H. Menzel: On the Structure of Cepheid Atmospheres.
Miss Jenka Mohr: The Relation of Light Curve to Period of Cepheids in the Large Magellanic Cloud.
Dr. Sergei Gaposchkin: Properties of Cepheids at the Minima of Period Frequency.
Dr. Theodore E. Sterne: Secondary Periods in Cepheids.
Mr. Daniel Norman: The Light Curve and Continuous Spectrum of SU Cassiopeiae.
Dr. Fred L. Whipple: Pressure Effects in Cepheid Atmospheres.
Miss Henrietta H. Swope: Classical Cepheids near the Galactic Center.
Dr. Samuel L. Thorndike: Report on a High Latitude Variable Star Field.
Dr. Harlow Shapley: Further Study of Cepheids through a Galactic Window.
Dr. Martin Schwarzschild: Stability Problems.

A summary of Dr. Shapley's paper is referred to elsewhere in these notes. Abstracts of the other papers will appear in a future number of POPULAR ASTRONOMY.

A Census of Cluster-Type Cepheids: In the course of reporting on the Cepheid variable stars in a southeastern galactic window, at the time of the conference on Cepheid variation at the Harvard Observatory, Dr. Shapley referred to the relatively high proportion of Cepheid variables with periods less than a day (cluster-type) in comparison with the classical Cepheids (periods greater than one day). It appears probable, from the recent discoveries of variable stars at Harvard, that there may be one hundred times as many cluster-type variables as there are ordinary Cepheids. A card catalogue has been compiled of all the cluster-

type Cepheids. There are 968 known in the globular star clusters, and 1254 outside of clusters, a total of 2,222.

As is well known, the cluster-type Cepheids are widely distributed in galactic latitude, in contrast to the high galactic concentration of classical Cepheids. Also, many of the cluster-type stars are at great distances from the galactic plane. It was noted in Dr. Shapley's report that over 20 of the cluster-type Cepheids are 10,000 parsecs or more from the galactic plane (not including those in some of the distant globular clusters). As members of the galactic system they indicate its thickness to be at least 50,000 light years. At great distances from the galactic plane, the density of stars is very low, and these faint cluster-type Cepheids and the globular clusters may be the principal members of the "aura" that appears to surround our flat Milky Way system.

The large number of cluster-type Cepheids has been one of the results of the systematic variable star surveys carried on photographically at Harvard as a part of the program of galactic measurements. A considerable number of cluster-type Cepheids have also been added to the list by German and Russian observers.

The Eclipsing Variable RZ Persei: The eclipsing variable RZ Persei has been the subject of observation and discussion for many years. There has certainly been strong evidence of a change in period, similar to that found in the well-known eclipsing star U Cephei. Professor R. S. Dugan in a recent paper from the Princeton Observatory has attempted to explain the observed change in period on the assumption that the system comprises three bodies. Dugan has observed the star over an interval of thirty years, and he emphasizes the importance of homogeneity in the observations and the value of a long series made over many years by a single observer.

He states that it seems possible to explain the change in period and the asymmetry of the observed O-C curve on the basis of a three-body system in which, probably, one star has an unusually small mass for its brightness and another is unusually faint for its mass. Dugan adds that if the inclination is 90° and if the third body is about equal in size to one of the eclipsing components, then an eclipse of the pair by the third body may be expected to occur every 37 years.

A New Eclipsing Star of High Mass: Another spectroscopic binary, H.D. 163181, has been shown to be an eclipsing variable. The spectrum is Oe5, according to Harvard, and Ble, according to Mount Wilson. The mass function has the exceedingly large value of 8.84 and the period of variation, according to Dr. S. Gaposchkin, is 12.0 days. McLaughlin suspected that this spectroscopic binary would be variable on the basis of the spectral changes described by Humason and Nicholson. The light curve of the star is of the β Lyrae-type with the two minima approximately of equal depth, and with a range of about half a magnitude. If additional observations confirm range, type of variation, and period, and if the spectrum of the secondary star can be measured, then the star looms as a very important one among eclipsing variables.

Auroral Observations: At first glance, auroral observations might seem to be not directly associated with variable star observations, but when one considers that aurorae are decidedly variable, both in time of occurrence and magnitude, their relation to such an observational technique may not seem too remote. Variable star observers, with their intimate knowledge of, and familiarity with, the constellations, should prove to be among the best fitted to engage in accurate observations of the aurorae. Dr. C. W. Gartlein of Cornell University is making a

direct appeal to amateurs, in particular, for observations of auroral phenomena, and he invites meteor and variable star observers to coöperate in the work.

The aim of such observations will be:

(1) To obtain data for plotting frequency of aurorae over the United States and Canada and possibly over a wider territory.

(2) To obtain times of occurrence of changes in auroral form such as from quiet arc to rays, or when curtains or draperies appear or end, etc.

(3) To obtain as complete descriptions of displays as the observers are willing to communicate.

To those observers who would care to participate in this program, a leaflet will be sent showing auroral forms and standard nomenclature, and giving instructions regarding methods of taking and tabulating the data. Report blanks and special reply cards will be sent with the leaflet. Variable star observers who are willing to coöperate in this program are requested to communicate with Dr. C. W. Gartlein, Department of Physics, Cornell University, Ithaca, New York.

Observers and Observations: A group of observers—Misses Hoffstetter and Pilnick, and Messrs. Heinmiller, Plueddemann and Simkins—working under the direction of Mr. James L. Russell at Baldwin-Wallace College, has contributed to these reports for the first time. Besides current observations of regular variables, Mr. A. W. J. Cousins of Durban, South Africa, has contributed several hundred observations made in earlier years of the variable star l Carinae, the 35-day period Cepheid. The list of observers, with the number of variables observed and the number of estimates made, is as follows:

Observer	Var.	Est.	Observer	Var.	Est.
Ahnert	40	244	Kearons	18	48
Andrews	1	1	Kelly	5	12
Baldwin	62	100	Kirkpatrick	41	126
Ballhaussen	11	11	Kozawa	21	395
Bappu	32	130	Loreta	140	384
Blunck	13	13	McNabb	4	12
Bouton	60	84	Murphy	26	42
Brocchi	40	106	Palo	2	2
Buckstaff	6	9	Peck	31	71
Callum	26	26	Peltier	111	131
Cousins	22	118	Pilnick	4	8
Dafter	11	28	Plueddemann	4	9
Diedrich	8	15	Purdy	5	5
Ellis	16	19	Rademacher	7	24
Ensor	32	40	Recinsky	5	13
Erro	37	37	Rosebrugh	14	37
Escalante	85	105	de Roy	13	76
Evans	18	18	Russell	5	15
Ferbald	3	4	Ryder	9	12
Focas	79	114	Seely	2	11
Franklin	6	6	Shafer	3	5
Gregory	105	105	Sill	78	106
Hartmann	136	230	Simkins	4	8
Heinmiller	4	8	Smith, F. P.	26	40
Herbig	97	218	Smith, F. W.	2	5
Hiett	16	31	Smith, J. R.	6	6
Hildom	23	53	Strelitzer	12	12
Hoffstetter	4	8	Treadwell	7	8
Holt	76	144	Webb	28	28
Houston	82	487	Woods	17	44
Howarth	14	19	Yamasaki	16	18
Jones, E. H.	96	362			

In spite of the reported cloudy conditions prevailing at many observing stations, a grand total of 4504 observations by 63 contributors is commendable.

Spring Meeting of the A.A.V.S.O.: The Spring Meeting of the A.A.V.S.O. is to be held on May 27-28, at the Ladd Observatory, Brown University, Providence, Rhode Island. There will be a joint meeting with the Skyscrapers Inc. on Friday evening, and the regular sessions will conclude with a trip to the Seagrave Memorial Observatory at North Scituate on Saturday afternoon.

April 18, 1938.

Notes from Amateurs

The New Haven Amateur Astronomical Society

On April 16 the New Haven Amateur Astronomical Society held its fifteenth meeting and adopted the Constitution and By-Laws presented by the committee.

Mr. Neale, chairman of the Telescope Making Group, reported that at the last meeting considerable interest was shown over the results obtained by the 4-inch reflector just completed by Mrs. Rademacher at whose home the meeting was held. A demonstration was made of cutting out a 6-inch mirror blank in almost one hour's time and the showing and explanation of Newton's Rings made with a neon light.

Mrs. Rademacher reported the observing of a brilliant fireball about ⅛ the size of the moon on the night of March 28, traveling a distance of about 15° with a slow motion. Dr. Rademacher corroborated his wife's report by stating that while driving in from Middletown the same evening he had observed three fireballs, one of which checked with the one observed by his wife.

Mr. Anyzeski reported that plans to observe the Lyrid shower were being made. Last year the shower was observed in conjunction with observers at Vassar College.

Mrs. Glowacki addressed the group on sunspots and said in part that the Europeans from the beginning of time up to 1610 were merely aware that there was a sun without much knowledge as to its nature, but, beginning with Galileo's telescope, observers became aware that there were spots on the sun and by timing the motion of these spots across the face of the sun and noting their disappearance and subsequent reappearance on the other side it was determined that the sun revolved in 28 days, and also the declination of its axis was obtained but this was about as far as they progressed until 1826 when Schwabe began a systematic study of the sun's surface which is still being carried on.

The Chinese records show ninety-five sunspots observed between the years 188 A.D. and 1638, a small number for such a long period but they were obviously naked-eye observations. The recurrences of large and numerous spots come in waves or cycles of 11½ years. Available records show one exception to this cycle for there was a period of almost seventy years at the end of the 17th century when there were practically none observed.

The speaker stated that a sunspot was a gigantic funnel-shaped vortex around which intensely hot gas whirls up releasing pressure and expanding rapidly, giving rise to intense magnetic fields, they come in pairs, one in each hemisphere with opposite polarity because their vortical motions are in opposite directions and they keep their polarity through two complete cycles (22 years) then change polarities.

These powerful magnetic fields are supposed to cause the magnetic storms which we have on the earth.

Sunspots vary from 500 to 60,000 miles in diameter and are not found on all parts of the sun's surface, but are usually confined to the space between latitudes 6° to 40° in both northern and southern hemispheres.

Mrs. Glowacki illustrated her address by several slides projected upon a screen, clearly explaining many points.

F. R. BURNHAM, *Secretary.*

820 Townsend Avenue, New Haven, Connecticut, April 20, 1938.

Amateur Astronomical Society of Los Angeles

The Amateur Astronomical Society of Los Angeles held its regular monthly meeting in the evening of April 14, 1938, at the clubhouse, 2606 W. 8th St. After the routine business had been disposed of, the speaker of the evening, Mr. G. H. Lutz, was introduced.

Mr. Lutz talked on the subject "Metal Mirrors for Large Telescopes." He told how Newton used a speculum metal mirror in the first reflecting telescope, and how metal mirrors were used for many years until they reached their zenith of popularity under the Herschels and Lord Rosse. Then, with the discovery of the process of depositing silver chemically upon glass, the vastly superior glass specula came into practically universal use. But now it seems as if the mirrors of the future will be made of metal, but of a type infinitely more practicable than the old speculum metal. Mr. Lutz then outlined the researches he has conducted toward the development of telescope mirrors made of stellite, invar, and other extremely hard and highly reflecting alloys. He exhibited several mirrors and flats made of these metals, and some electrolytically coated with rhodium, one of which was nearly twenty years old, and still showing no perceptible signs of tarnishing or dimming.

The speaker also remarked upon the possibilities of electrolytic deposition of metals upon optical surfaces such as gratings and mirrors. This results in nearly perfect duplication, but the warping of the metal cannot at present be overcome. For this reason, metal replicas of gratings cannot be used for accurate work. Mr. Lutz exhibited a small diffraction grating ruled at Mt. Wilson on the surface of a rhodium-coated disk of pure nickel. This metal is markedly superior to speculum metal for gratings, due to the absence of crystalline irregularities in the metal, with the consequent possibility of ruling more perfect gratings. A full-scale diagram was shown of the 200-inch pyrex mirror now under construction, and a proposed 300-inch metal speculum. In such large sizes, the metal mirror would cost about half as much as the glass, and, due to the practicability of casting it much thinner in relation to the diameter, it would be only a fraction as heavy.

After the chairman expressed the Society's appreciation of Mr. Lutz's fine talk, the meeting adjourned to refreshments. There were fifty-seven present.

April 15, 1938. GEORGE HERBIG, *Secretary.*

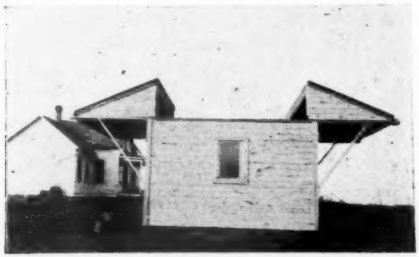
A Small Observatory

After some years of observing variable stars with a portable 3-inch telescope, I naturally desired something better. Therefore I was much pleased when Mr. Campbell of Harvard Observatory wrote me last spring offering me the use of the 5-inch telescope formerly belonging to the late William Tyler Olcott on condition that I furnish an observatory to shelter it.

Fortunately, I knew of a man whose skill was equal to the construction of a sliding roof observatory. He was Henry Hoyem, the local carpenter and contractor and a friend of mine since my boyhood. I prepared my first preliminary plans and we talked them over. The final plans for the structure emerged. The observatory was completed during the first week of November and the Olcott telescope was mounted on November 16, 1937.

The observatory is a frame structure, with side walls six feet high from foundation to eaves. It is ten feet square. There is a window on the south side and the door is on the north. The foundation is of concrete and the sills are bolted to the foundation.

The sliding roof requires closer description. It is two feet high from the eaves to the gable peak and is divided into halves along the peak. The rollers are iron pulley wheels, five inches in diameter. They turn on iron bolts of a diameter just sufficient to fit snugly inside the holes for the shafts. These wheels, three to each side of each half of the roof, twelve in all, are held in place between two



NOAH W. MCLEOD'S OBSERVATORY

parallel lengths of 2x4 timber, five feet in length, one pair of timbers on each side of each half of the roof. The tracks on which the wheels run are two twenty-foot lengths of three-quarter-inch pipe, running in an east-west direction, and supported by 2x6 timbers of the same length. For ease in handling, rope handles are attached to each half of the roof. Two pairs of heavy hooks hold the roof in place when it is closed. Each half of the roof can be moved quite easily with one hand.

The concrete pier on which the telescope is mounted is at the center of the observatory. It is five feet high above ground and below ground it is sunk to a depth of eight feet to get below the frost line. The pier is two feet square at the ground level and tapers to ten inches square at the top. A heavy block of hard wood, ten inches square and an inch and a half thick is bolted to the top of the pier. The base of the mounting of the Olcott telescope is bolted to this block.

Three wooden boxes of various sizes are used for seats. A larger box, with shelves, is used as a combined cabinet and desk.

With the Olcott telescope housed in its new observatory I plan not only to observe variable stars, but to engage in a program of lunar and planetary observation, with particular reference to the changes in detail on the lunar surface.

This observatory was made possible through the financial help of the local district of the North Dakota Federation of Women's Clubs, who contributed the major part of the cost. The total cost of construction was $98.26.

Christine, North Dakota, March 24, 1938. NOAH W. MCLEOD.

General Notes

Professor W. O'Leary has retired from the directorship of the Riverview College Observatory, Sydney, N. S. W. The reverend Dr. D. J. K. O'Connell, S.J., has been appointed as his successor in this position. Professor O'Leary will, however, continue to work at the Observatory.

Mr. Hugh M. Johnson, an amateur astronomer living at 3207 Cornell Street, Des Moines, Iowa, is making a study of the planet Mercury, and is desirous of entering into communication with any other amateur astronomer working along similar lines. He suggests that an exchange of drawings and reports might prove mutually beneficial.

Professor A. O. Leuschner, Director of the Students' Observatory, University of California, according to an announcement in the *Oxford Gazette,* will give the Halley Lecture for 1938 on June 16 on the subject "The Hecuba Group of Minor Planets." Other American astronomers who have been honored by the invitation to give the Halley Lecture are: William Wallace Campbell, Harlow Shapley, Henry Norris Russell, and Edwin Powell Hubble.

Astronomical Meetings of Section D at Ottawa.—In connection with the summer meeting of the American Association for the Advancement of Science to be held at Ottawa June 27 to July 2, the section on astronomy (D) is planning to meet at the Dominion Observatory of which Dr. R. M. Stewart, vice-president of the section, is director. One of the principal features of the program will be a joint session with the Royal Astronomical Society of Canada in which there will be a symposium on atmospheric ozone in charge of Dr. Brian O'Brian of the University of Rochester.—HARLAN TRUE STETSON, Secretary for Section D.

Astronomy Department Reinstated at Brown

A Department of Astronomy has been established at Brown University, effective with the beginning of the academic year 1938-39. Professor Charles H. Smiley has been made chairman of the department and director of Brown's Ladd Observatory.

The new department will offer courses in descriptive and practical astronomy, and selected topics in the field. Instruction will include demonstrations and the use of astronomical equipment at the observatory, work which has been conducted by the Department of Mathematics since 1914.

Astronomy, one of the first sciences to be introduced into the curriculum in Brown's earliest days, dates back to 1786, when Dr. Benjamin West was appointed professor of mathematics and "astronomical studies." There was a separate Department of Astronomy at Brown from 1883 until 1914, when the late Professor Winslow Upton was in charge. The Ladd Observatory was built during his 31 years at Brown, and was completed in 1891.

Professor Smiley, who has been at Brown as an assistant professor of mathematics since 1930, received national attention when he photographed the total eclipse of the sun last June 8 in Peru with a Schmidt camera. He is believed to have been the first to record the zodiacal light in the neighborhood of the sun. He holds A.B., M.A., and Ph.D. degrees from the University of California.

Collection of Time Pieces

In 1926, the late James Arthur, of New Rochelle, New York, presented to New York University one of the largest and most comprehensive historical collections of clocks and watches in existence.

The collection, in the Arthur Room of Gould Memorial Library on the campus at University Heights, consists of more than eighteen hundred time pieces and presents a story of the evolution of time keeping from the simplest sundial and hour glass to clocks having multiple dials and highly complicated mechanisms.

Mr. Arthur assembled the collection over a period of forty years, and at an expenditure of well over $150,000. Since the donation of the collection to the University about fifty clocks and two hundred watches, comprising many rare and valuable specimens, have been added to it. Many of the additions were donated, others purchased.

The will of the donor provided New York University in 1931 with a generous bequest to maintain and enhance the collection, and to provide an annual lecture on "Time and Its Mysteries."

The first four lectures have been published in one volume entitled "Time and Its Mysteries," Series I, by New York University Press (1936).

Dr. John Dewey, Professor of Philosophy in Columbia University, delivered the seventh in this series of lectures on April 21. His subject was "Time and Individuality."

Book Reviews

Portraits of Eminent Mathematicians, by David Eugene Smith. (Scripta Mathematica, New York City.)

In 1936, portfolio number one, containing twelve portraits and brief biographical sketches, was issued. The names included in this portfolio are: Archimedes, Copernicus, Viète, Galileo, Napier, Descartes, Newton, Leibniz, Lagrange, Gauss, Lobachevsky, Sylvester.

This was so well received that, in 1938, portfolio number two has been published. In it we find portraits and biographical sketches of: Euclid, Cardan, Kepler, Fermat, Pascal, Euler, Laplace, Cauchy, Jacobi, Hamilton, Cayley, Chebishef, Poincaré.

It is at once evident that the selection of those for inclusion was not made on the basis of chronological sequence or of geographical distribution. The names were chosen, as we are told in the introduction to portfolio number two, "in such a way as to encourage the study of the individuals and of the period in which they lived and worked. In this way the reader is at no time led to feel that progress in mathematics is confined to a single hemisphere, country, era, race, or class."

The photographs are done in a very finished manner and are of suitable size for framing. With the brief but pertinent biographical sketches they surely afford a valuable aid to mathematical teaching, especially in courses having to do with the history of the science.

The price stated is $3.00 for each portfolio.

The Observational Approach to Cosmology, by Edwin Hubble, ix + 68 pages. (The Clarendon Press, Oxford, 1937. Price $2.50.)

In the fall of 1935 Dr. Hubble delivered six Silliman lectures at Yale University on *The Realm of the Nebulae* and these have since been published in a book of some 200 pages by the Yale University Press. Last year he was invited to deliver the Rhodes Memorial Lectures at Oxford that are given by some former Rhodes Scholar, and these three lectures are now presented by the Clarendon Press in the little volume that is before us; this is in a sense a summary of the matter that appears in *The Realm of the Nebulae,* but the interval of only a few months between these two series of lectures has witnessed important advances in Dr. Hubble's work on the extra-galactic nebulae that are briefly incorporated in the present volume.

Dr. Hubble has devoted some twenty years effort to this subject and has had the advantage of the use of the unrivaled facilities of Mount Wilson Observatory. His work has of course constituted the chief contribution to our knowledge of extra-galactic nebulae and to the cosmological deductions that may be based upon this knowledge. But the history of the subject is long and is one in which many have played a part. Before the days of photography only a few spiral nebulae were known. In 1900 Keeler, after working only a few months with the Crossley reflector of the Lick Observatory, published a paper* that appears to be too little known, in which he showed that more than 100,000 of these nebulae were within reach of his telescope. The next important step was taken by V. M. Slipher who, working on the brightest dozen or so of these objects with a spectrograph attached to the comparatively small telescope at Flagstaff, and making photographs that necessitated the accumulated exposure on several successive nights, was able to show that the nebulae give a composite stellar spectrum, that they are rotating, and most important of all that, with two exceptions, they are all apparently receding from us at high velocities. A method of estimating the distances of these nebulae was indicated in 1913 by Hertzsprung and applied by him to the Lesser Magellanic Cloud: this was by means of the Cepheid variables and the assumption (since very fully substantiated) that the absolute brightness of these variables can be accurately inferred from their periods. This method was followed with great success by Shapley in his work on the globular clusters but at that time could not be generally applied to spiral nebulae because so few Cepheid variables had then been detected in these objects. This was Hubble's first important contribution and it did away with what we now know to be gross underestimates of their size and distances. These underestimates flowed from the statistical combination of Slipher's velocities with internal proper motions in the nebulae, proper motions that we now have every reason to believe are vitiated by large systematic errors.

Another misapprehension has more recently been dispelled through the work of Trumpler of the Lick Observatory. It was formerly supposed that spiral nebula are very unevenly distributed in space, showing a marked avoidance of low galactic latitude and a preference for the poles of the galaxy. Trumpler's detection and evaluation of "galactic absorption," absorption within our own system, supplies the key to this puzzling apparent distribution, and Hubble finds that after allowing for such absorption the spiral nebulae are pretty evenly scattered throughout space.

This conclusion, as well as others of not less importance in the book before

*The Crossley Reflector, *Astrophysical Journal,* **11**, 325.

us, involves a knowledge of relative distances of these nebulae throughout their whole range of distribution and apparent brightness. The Cepheid variables furnish this datum for only a few of the nearest nebulae. For somewhat more distant ones good estimates may be based on the assumption (similar to that made by Shapley for globular clusters) that the brightest stars in each nebula have the same absolute magnitudes. But this expedient does not carry us much farther out into space, for only a very small percentage of these objects can be resolved into separate stars. Next Dr. Hubble tries the assumptions that the total light emitted by each nebula is a constant, and that they are all of the same linear dimensions. Both these assumptions prove to be fairly well founded; with regard to linear dimensions, for example, Hubble asserts that the majority of nebulae are found in the range between half a certain standard size and double it.

The most interesting fact concerning the nebulae, and the most puzzling, is the red-shift in spectral lines. All the nebulae show the H and K lines of calcium near wave-length 3900, and in the brighter ones iron and hydrogen lines also appear. Except for a very few of the nearest nebulae these lines are always shifted toward the red end of the spectrum, and by amounts that are proportionate to the wave-length. This is just as it should be if the shift is due to radial velocity and this was the interpretation put upon the observations when only the nearest of the nebulae had been investigated. But Hubble and his colleague Humason have found that the shift increases in proportion to the distance of the nebula; Humason has found for the most distant of them that can be observed that the red-shift corresponds to a velocity of more than 40,000 km a second. It is difficult to accept such velocities. For one thing, if these velocities are extended back into the past, we come to an epoch only 2,000,000,000 years ago when all the nebulae must have been in the immediate neighborhood of each other. There are rocks in the earth's crust that are known to be as old as this. Perhaps the velocities have been more moderate in the past, but in any case this initial epoch can hardly be more than 10,000,000,000 years ago. How can we escape this conclusion? Only by supposing that the red-shifts are not due to velocity but are caused by some "new principle of nature." Dr. Hubble points out a way in which this alternative may possibly be tested: if these are real velocities then the nebulae are made to appear fainter than they really are because their recession would yield fewer quanta of light a second than if they were stationary. An attempt is made in this work to apply this test; but the reviewer feels, as probably Dr. Hubble himself feels, that as yet it is not very convincing. All of his colleagues will look for the sequel of this and other inquiries that Dr. Hubble indicates, with the liveliest of interest. The continuation of these researches constitutes one of the best arguments that has been advanced for the prospect of a successful career for the 200-inch reflector that will soon be available.

FRANK SCHLESINGER.

Yale Observatory, 1938 March 26.